FOUNDRY TRADE JOURNAL

Established 1902

WITH WHICH IS INCORPORATED THE IRON AND STEEL TRADES JOURNAL

Vol. 87 Thursday, December 1, 1949 No. 1735

49, Wellington Street, London, W.C.2

Grams: "Zacatecas, Rand, London"

'Phone: Temple Bar 3951 (Private Branch Exchange)

PUBLISHED WEEKLY: 26s. per annum (Home and Overseas)

Rolled Cast Iron

It is just over ten years ago since in this column attention was drawn to the fact that Mr. Duncan P. Forbes, president of the Gunite Foundries, Rockford, Illinois, had rolled cast iron. The article in question reads:—"It appears from the account which is given that an order was received by the foundry for malleable cast-iron plates some 4 ft. square and about ¼ in. or ⅜ in. in thickness. Attempts to produce such plates by sand casting failed. Where, by good fortune and the use of a carefully-controlled pouring and casting technique, some were knocked out in one piece, these were found to fracture during malleablising. A happy inspiration led to attempts being made to cast the initial white iron into billets and then to roll these (in somebody else's mill, it may be observed) into the required form. After many setbacks, the goal was achieved and a plate obtained which was successfully heat-treated, producing a material somewhat akin to both ordinary grey iron and to malleable cast iron. It is indicated that grey iron was also successfully rolled, but that its uses appear somewhat more limited than those of rolled white iron."

This week we have received for review a book* on this subject written by Professor E. Piwowarsky and Dr. A. Wittmaster which shows the enormous technical progress which has been made in the last decade. The material of which they write is cast iron of 11 to 18 tons tensile which, having been hot-worked, shows a strength range varying between 55 and 75 tons per sq. in., and with this are associated elongation values from 3 to 10 per cent. Because of the graphite present in the structure, the product has the damping capacity of cast iron. Here, then, is a new material available to the engineer; its properties are somewhat different from rolled or forged steel or malleable cast iron, and but little resemble cast iron as cast. The material can be forged as well as rolled. We see from a proposed layout that both cupolas and electric furnaces are included in the plant required. Naturally enough, with such a process, yielding a novel material, much intensive work will have to be done before the full range of its properties and applications are understood. Yet preferably, if this alloy is to find a place in the range of engineering materials, its name should be changed, as "rolled cast iron" seems to us to be a misnomer.

The question that arises from the subject matter of this book is, whose task is it to undertake the development? It is no longer a foundry product, but at the moment foundrymen are more familiar with the production of the raw material than are other ferrous metallurgists. Again, as a raw material, can it compete with the steel ingot as taken from the soaking pit? For the ingot, liquid pig-iron has been transferred to a mixer and then, in large capacity units, has been converted to steel. Finally, if the process shows real potentialities, would not liquid pig-iron be processed, so removing the process from the foundry? The answers to these questions may be in the book, for our limited knowledge of German precludes us from giving it the study it deserves. However, arrangements have been made for its review, and we personally would appreciate a translation of the work into English.

* "Gewalztes Gusseisen," published by Girardet, Essen. Price 9.30 DM.

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Forty Years Ago

In the December, 1909, edition of the FOUNDRY TRADE JOURNAL, the Editor was worrying about brass melting losses and, like his contemporaries, paid far too much attention to oxygen and too little to hydrogen. The modernity of the construction, equipment and operation as disclosed by an illustrated description of the [American] Aluminium Casting Company is almost unbelievable. It would, with the provision of a few conveyors be regarded to-day as comforming to current conceptions. There is a remarkable reproduction of a photograph of the "new" foundry of Hunt Brothers (Oldbury), Limited. It would appear that the quality of the super-calendar paper then used is a major factor, plus real care in blockmaking. Another picture, of a 100-ton crane installed in the works of Vickers, Sons & Maxim, Limited, is equally clear, though touching-up is obvious. The death is announced of Mr. S. Russell, J.P., a well-known malleable ironfounder of Walsall.

Two-town Plan for Recruitment

With the object of popularising the industry and attracting young people to the foundry trade, a joint committee from foundry firms has been formed for Willenhall and Wednesfield, Staffs, with a Willenhall ironfounder, Mr. William James, as chairman. An equal number of representatives of employers and workpeople compose the committee, the main function of which will be to advise on questions affecting recruiting and training of juveniles. The non-ferrous foundry trades probably will be included later.

A general scheme of training for moulders has been considered and, when plans are more advanced, it is hoped to obtain the active support of employers for their implementation.

DAVID BROWN & SONS (HUDDERSFIELD), LIMITED, leading makers of steel castings for the construction of aircraft equipment and heat-resisting alloys for aircraft gas turbines, have entered into a "technical-aid" agreement with Sambre et Meuse, the well-known French founders, under which Sambre et Meuse will be able to make these castings for France and the French Colonies and Protectorates. David Brown will put information about casting techniques at the disposal of the French firm, including that relating to the centrifugal process, and there is to be an interchange of technicians between the two organisations for liaison and instruction. Permission has been granted for a new specialist foundry to be set up at Feignies, on the French/Belgian border.

OF THE 400 to 500 moulders, members of Dundee District Amalgamated Union of Foundry Workers, who went on strike last week, about 300 have returned to work. The strike was caused by the employment of three women coremakers in Wallace Foundry, Dundee, belonging to Urquhart, Lindsay, Robertson Orchar, Limited. At this foundry, 130 workers are still idle.

Forthcoming Events

DECEMBER 5.

Institute of British Foundrymen.

Sheffield Branch :—"The Manufacture of Cast Magnets," by A. Braybrook and D. Hadfield, at the Royal Victoria Station Hotel, Sheffield, at 7.30 p.m.

DECEMBER 6.

East Anglian Section :—"Simple Aids to Production," by S. R. Bridges, at the Central Hall, Public Library, Ipswich, at 7 p.m.

Chemical Engineering Group.

"Underground Corrosion of Ferrous Metals in Light of Recent Research," by Dr. W. H. J. Vernon and Dr. K. R. Butlin, at the Geological Society, Burlington House, London, W.1, at 5.30 p.m.

Institute of Physics

Scottish Branch :—"The Physical Explanation of the Strength of Metals," by Prof. N. F. Mott, F.Inst.P., F.R.S., at the University of Glasgow, at 7 p.m.

Institute of Metals.

S. Wales Local Section :—"Refractories, with Special Reference to Slag Corrosion," by Prof. R. Higgins, Ph.D., A.R.T.C., F.I.M., at the University College, Metallurgical Department, Singleton Park, Swansea.

DECEMBER 7.

Institute of Production Engineers.

Wolverhampton Section :—"Foundry Technique in Relation to Engineering Production," by G. R. Shotton, at the Dudley and Staffordshire Technical College, Dudley, at 7 p.m.

DECEMBER 8.

Institute of British Foundrymen.

London Branch :—"Casting Copper Lead Bearings," by P. D. Liddiard, B.Sc., F.R.I.C., A.I.M., F.C.S., and P. G. Forrester, at the Waldorf Hotel, Aldwych, London, W.C.2, at 7 p.m.

Institution of Production Engineers.

Derby Sub-section :—"Industrial Design," by W. N. Rodgers, at Becket Street Sales Room, Derby, at 7 p.m.

Institute of Physics

London and Home Counties Branch :—"Some Physical and Chemical Effects of Friction," by Dr. F. P. Bowden, F.Inst.P., F.R.S., at 47, Belgrave Square, London, S.W.1, at 5.30 p.m.

DECEMBER 9.

Institute of British Foundrymen.

West Wales Section :—Discussion "Some Difficulties in Making Certain Iron and Steel Castings," at the Canteen, Richard Thomas & Baldwins, Limited, Landore Works, Swansea, at 7 p.m.

DECEMBER 10.

Scottish Branch :—"Relations Between the Pattern Shop and the Foundry," by Robert Connell, at the Royal Technical College, George Street, Glasgow, at 3 p.m.

Bristol Branch :—"The National Foundrycraft Training Centre," by A. Wormleighton, at the Grand Hotel, Broad Street, Bristol, at 3 p.m.

Newcastle Branch :—"Defective Castings," by N. Charlton, at the Neville Hall, Westgate Road, Newcastle-upon-Tyne, at 6 p.m.

Leeds Association of Engineers.

84th Anniversary Dinner, at the Hotel Metropole, Leeds, 1, at 7 p.m.

WE regret that in the "Forthcoming Events" column of the November 3 issue of the JOURNAL it was announced that at the November 7 meeting of the Sheffield Branch of the Institute of British Foundrymen, a Paper, "Incentives for the Future," would be presented by J. G. Bailes. The announcement should have read:—"The Development of Foundry Sand Control," by G. L. Harbach. The Paper by Mr. Bailes was actually given on October 3.

What is Acicular Cast Iron?*

Theoretical Considerations and Production Details

By W. W. Braidwood

Nickel-molybdenum cast irons have been made for many years. Occasionally, irons of this general type were found, somewhat inexplicably, to exhibit exceptional strength and toughness, allied with high machinable hardness. The structures of these exceptional irons were recognised as distinctive, but an understanding of why they occurred and how their production could be controlled was not developed until the systematic study of the subject by Flinn and Reese in 1941."†

Since that time, acicular iron has come into regular and increasing use for many applications which require the combination of properties outlined. During the war years particularly valuable service was rendered by acicular iron in direct and indirect production of munitions and, in suitable instances, in substitution for steel, and Grade 26 of B.S. 1452, 1948, was introduced primarily to cover irons of the acicular type.

The object of this Paper is to give the practical foundryman and foundry metallurgist an explanation of the theory, and guidance on the practice, of acicular iron production. Since this is a Paper by a practical man for practical people, the subject matter will be kept as straightforward and as simple as possible, even at some expense of absolute precision.

*Paper read before several branches of the Institute of British Foundrymen. The Author is on the research and development staff of the Mond Nickel Company, Limited.

†Bibliography will appear with the final instalment.—EDITOR.

Normal Transformations

To understand the acicular structure, one must begin with consideration of ordinary unalloyed cast iron and the changes of state which accompany cooling of the solid metal. Above a certain range of temperature, which varies according to the composition of the iron and the rate of cooling, but which is known as "the critical range," the atoms of iron are arranged in a face-centred cubic lattice. Iron with this type of lattice is known as gamma iron; it is non-magnetic and is able to retain carbon in solid solution. The solid solution of carbon in gamma iron is termed austenite.

On cooling to below the critical temperature, the atomic pattern undergoes transformation. It remains cubic, but the cubes become body-centred. This change of state is accompanied by an expansion; iron with this type of lattice is magnetic and is known as alpha iron. This form of iron cannot retain carbon in solid solution. If the rate of cooling through the critical range is sufficiently slow, adjustment of the lattice range place readily and in grey cast irons the carbon previously present in solid solution is rejected, partly as graphite, but mainly in the form of plates of iron carbide in association with layers of ferrite, to give lamellar pearlite, as illustrated in Fig. 1.

If the rate of cooling is more rapid, transformation takes place less readily and at somewhat lower tem-

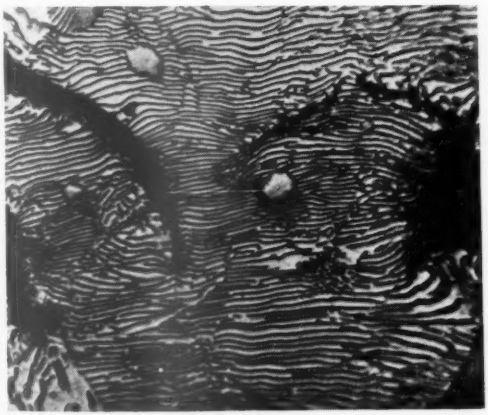


FIG. 1.—COARSE, LAMELLAR PEARLITE, ETCHED (× 1,000 MAGNIFICATION.)

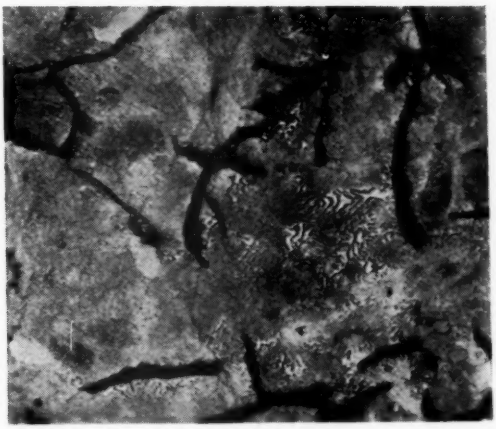


FIG. 2.—FINE, LAMELLAR PEARLITE, ETCHED (× 250.)

What is Acicular Cast Iron?

perature. It is found, however, that the product undergoes some change—the pearlite becoming progressively finer, as shown in Fig. 2. With further increase in rate of cooling, the pearlite will become so fine as to be be unresolvable under the microscope. Structures of this type, shown in Fig. 3, are sometimes described as sorbitic pearlite.

If cooling is faster still, and continuous, all transformation of the progressive type is suppressed and transformation of an instantaneous type will take place at much lower temperature, in the range of 250 to 150 deg. C. This results in the formation of martensite in which carbon is retained in enforced, super-saturated solid solution in alpha iron. This structure, shown in Fig. 4, is characterised by high hardness. It is seen, therefore, that in unalloyed cast iron there are two ranges of temperature in which transformation occurs most readily. These are:—The high range, approximately 700 to 550 deg. C., in which progressive transformation takes place, with formation of pearlite in one or other of its forms, and the low range, approximately 250 to 150 deg. C., at which transformation takes place instantaneously, with formation of martensite.

By a simple technique known as isothermal quenching, one can assess the tendency to transform at any temperature. The specimen is first held above the critical range to ensure that the iron is in the gamma condition, and then quenched into a suitable bath, usually of molten lead or fused salt, maintained at the temperature selected for study. The progress of transformation can then be observed by any of the following methods:—

(*a*) Measuring accurately, by dilatometer, the small expansions which accompany transformation.

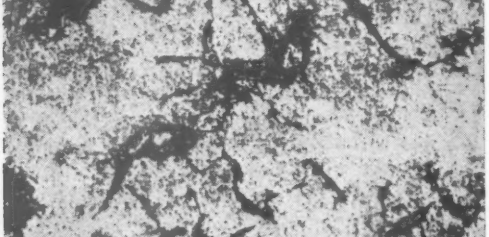


FIG. 3.—SORBITIC PEARLITE, ETCHED (× 500.)

FIG. 4.—MARTENSITIC GREY IRON, ETCHED (× 500.)

(*b*) Determining the increases in magnetic response which are effected by transformation.

(*c*) Examining, under the microscope, specimens removed from the bath at known intervals of time.

In such manner the times taken for inception and completion of transformation at each temperature may be observed. If these times are plotted against temperature and the points linked up, curves of the general type, shown in Fig. 5, are obtained. For simplicity the single-line curve shown expresses the times taken

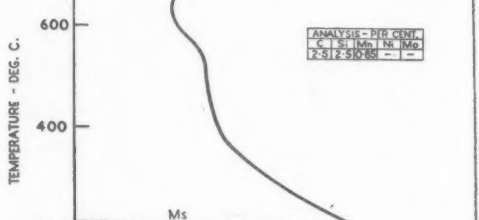


FIG. 5.—SIMPLIFIED "S" CURVE, SHOWING TIMES REQUIRED FOR 50 PER CENT. TRANSFORMATION IN UNALLOYED CAST IRON.

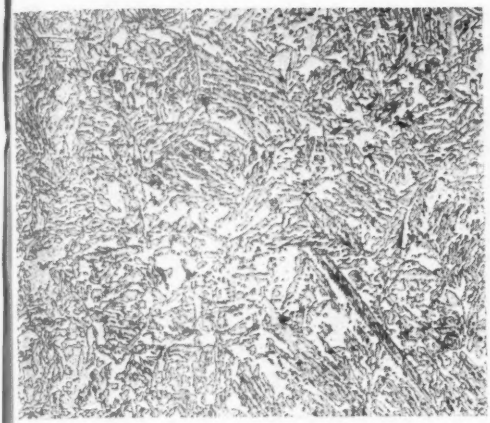


FIG. 6.—ACICULAR STRUCTURE PRODUCED IN A 1¼ PER CENT. SILICON, 2¼ PER CENT. NICKEL STEEL, ISOTHERMICALLY QUENCHED AT 400 DEG. C., AND HELD FOR ONE HOUR. ETCHED (× 500.)

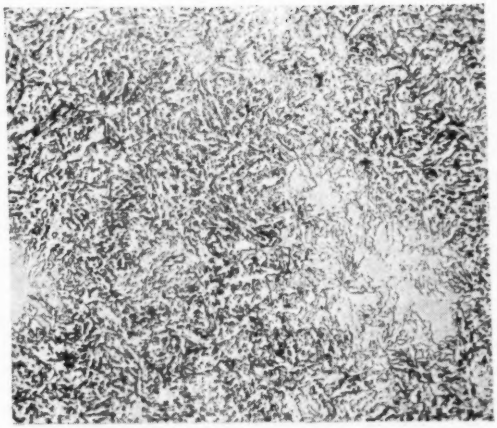


FIG. 7.—SAME MATERIAL AS FIG. 6, BUT HELD 20 HOURS AT 400 DEG. C. ETCHED (× 500.)

for 50 per cent. transformation. This is a so-called "S" curve; the one illustrated relates to unalloyed grey iron. (A logarithmic scale is used for time so that the graph may be of reasonable length and yet give accurate readings, particularly for the shorter periods.)

The two regions of rapid transformation are clearly shown and between these ranges of temperature there is seen to exist a zone of low transformation velocity; that is, of reluctance to transform. This is the "bay" of the "S" curve. Therefore, if an unalloyed iron is cooled at a rate sufficiently rapid to prevent transformation in the high-temperature range, that is, at the "nose" of the curve, it will not normally transform in this intermediate zone, but will remain unchanged until it cools to the low range and martensite is produced.

Intermediate Transformation

It is possible, however, by holding the specimen for a sufficient time in the intermediate range of temperature, to effect transformation by a mechanism different from that which forms pearlite or that which gives martensite. The product, moreover, is a structure which is neither pearlitic nor martensitic. Fig. 6 shows the intermediate structure produced in a special steel of composition corresponding to that of the matrix of a nickel cast iron, and which actually contained:—C, 0.66; Si, 1.78; Mn, 0.92; S, 0.009; P, 0.038; Ni, 2.30, and Mo, 0.04 per cent. This specimen was quenched into a bath maintained at 400 deg. C. and was held therein for one hour. Transformation is seen to be well advanced. Fig. 7 shows the same steel held at the same temperature (400 deg. C.) for 20 hrs., by which time transformation was virtually complete. It is obvious that the structure so produced is different from pearlite and from martensite.

Systematic study by many investigators has shown

FIG. 8.—UNALLOYED GREY IRON PARTIALLY TRANSFORMED AT 480 DEG. C. ETCHED (× 1,000.) (FROM HILLIKER & COHEN.)

What is Acicular Cast Iron?

that intermediate transformation is unlike that which takes place in the higher- and that which occurs in the lower-temperature range. Like the pearlite transformation, it is a process involving nucleation and growth, but whereas pearlite is nucleated by cementite, ferrite is the nucleant in the case of the intermediate structure. The low-temperature transformation is different from both of the above processes, in that the product, martensite, is formed instantaneously and not by nucleation and growth.

The Intermediate Structure

The understanding of the intermediate structure can be increased by examination of specimens caused to transform at progressively lower temperatures. This has been done by Hilliker and Cohen,[8] from whose work the next five illustrations are taken. These depict the structures produced in identical specimens of unalloyed cast iron, partially transformed at selected temperatures. Partial transformation was arranged, deliberately, in order to show the intermediate products most clearly. Fig. 8 shows the structure obtained on quenching into a bath maintained at 480 deg. C.—that is, in the upper part of the intermediate range. The ground mass is light-etching martensite which is actually formed on the subsequent rapid cooling to room temperature. The intermediate product is clearly seen in the form of light-etching "needles" of ferrite. Fig. 9 shows the

FIG. 9.—SAME MATERIAL AS FIG. 8, PARTIALLY TRANSFORMED AT 400 DEG. C. ETCHED (×1,000) (HILLIKER & COHEN.)

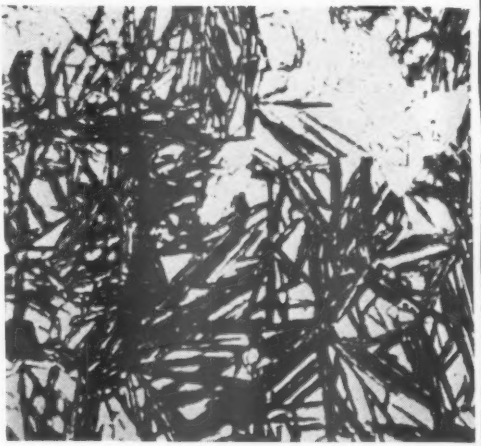


FIG. 10.—SAME MATERIAL AS FIG. 8, PARTIALLY TRANSFORMED AT 315 DEG. C. ETCHED (×1,000) (HILLIKER & COHEN.)

result of transformation at 400 deg. C. The ferrite needles are longer, more angular and darker.

With transformation effected at 315 deg. C., *i.e.*, in the lower part of the intermediate range, the ferrite needles are even longer, darker still and more distinctly angular, all as shown in Fig. 10. Transformation at 260 deg. C. is less effective, as shown in Fig. 11, by the smaller proportion of intermediate product. The needles are long, thin, very angular, and intensely dark. For the sake of completeness, Fig. 12 is included. This shows the result of direct quenching to room temperature, giving a structure which is martensitic, with no trace of intermediate product.

From their appearance under the microscope, the intermediate structures might be placed in two main groups:—(*a*) Those consisting mainly of the light-etching, feathery product formed in the upper part of the intermediate range, and (*b*) those consisting mainly of the darker-etching angular products formed in the lower part of the intermediate range. These structures, however, are not really distinct, metallographically, since they are all part of a continuous series formed by a common mechanism. It must be remembered, moreover, that isothermal quenching, though essential for precise study of the progress of transformation, can rarely be applied in practice. The normal production procedure is to control the progress of transformation by another method, that of alloying, while allowing the casting to cool in the mould. The resultant structures are less definitely distinguishable, since transformation progresses at steadily falling temperature. Nevertheless, it is usually possible to describe acicular structures

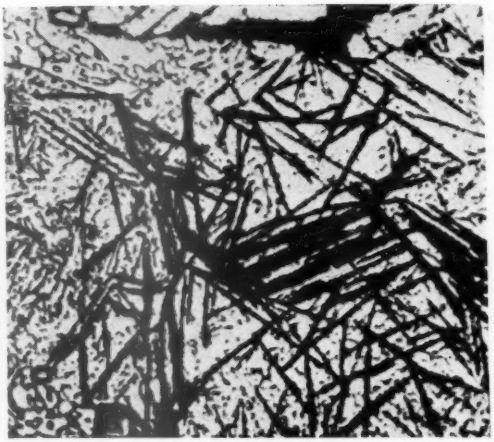


FIG. 11.—SAME MATERIAL AS FIG. 8, PARTIALLY TRANSFORMED AT 260 DEG. C. ETCHED (×1,000) (HILLIKER & COHEN.)

as "light-etching," indicating that transformation has taken place mainly in the upper intermediate range, or as "dark-etching" when transformation has been effected mainly in the lower, intermediate range.

In a tribute to E. C. Bain,[1] who, with Davenport, was responsible for the first systematic study of transformation at intermediate temperatures, the intermediate structures have been given the generic title of "Bainite." The light-etching variety has been termed "upper-bainite" and the dark-etching "lower-bainite," but, probably in order to avoid misunderstanding due to previous specific usage of these terms, all of the intermediate structures in cast iron have been given the name acicular, which means "needle-like." This is not an ideal description and may yet be superseded by something more correct. For the present, it is necessary for foundrymen simply to know exactly what is meant when the term "acicular structure" is used.

Formation of the Intermediate Structure

But what is actually taking place during intermediate transformation? Why are there lighter- and darker-etching structures and what are their constituents? The work of Flinn, Cohen and Chipman[10] has done much to answer such questions. According to these investigators, intermediate transformation may be considered to progress somewhat as follows:—Because the transformation begins with precipitation of ferrite and develops by growth of ferrite needles, atoms of carbon must be re-distributed. The ferrite formed in the upper intermediate range is soft. Moreover, reheating of this constituent to just below the critical range does not bring about precipitation either of carbide or of graphite. For these reasons it may be said that carbon is not retained in the ferrite first formed. Some carbide may occasionally be identified adjacent to the ferrite, but undoubtedly most of the carbon atoms initially rejected diffuse into the surrounding austenite. Boyles[10] takes this explanation further by postulating that the migrating carbon atoms diffuse through the austenite to deposit on the existing graphite.

This diffusion takes place readily in the early stages, when the mobility of the carbon atom is relatively high. Subsequently, however, with falling temperature resulting in lower mobility, and with ferrite growth causing enrichment of the remaining austenite, diffusion of carbon is much less rapid and this probably explains the sluggishness of the transformation in its later stages. In these later stages and in the lower range of intermediate temperature, carbon is to an increasing degree entrapped in the ferrite and precipitates there, causing progressive darkening of the phase. Ultimately, the carbon-rich austenite begins to decompose into an intimate aggregate of ferrite and carbide. The austenite, however, does not transform completely in the intermediate range; some breaks down to martensite on subsequent cooling and some is retained at room temperature. From all of the foregoing it will be realised that there can be wide variation in metallographic appearance among acicular structures, though they are all the product of a single progressive type of transformation. Similarly, the mechanical properties of acicular cast irons are capable of variation over a wide range according to the precise structure produced.

(To be continued)

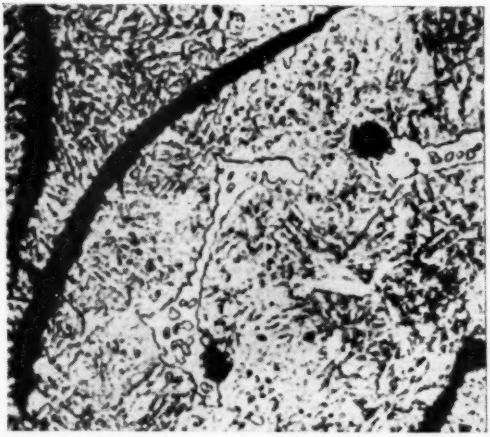


FIG. 12.—SAME MATERIAL AS FIG. 8, QUENCHED TO ROOM TEMPERATURE. ETCHED (×1,000) (HILLIKER & COHEN.)

Automatic Moulding

By A. Graham Thomson

An output of 120 boxes an hour is being achieved in a British foundry by a single man operating two machines. This remarkable performance indicates the progress which has recently been made towards the ultimate goal of fully-automatic moulding. It represents the latest stage in a sequence of developments which began with the introduction of the first hand-operated machines in the foundry.

The scope for mechanical moulding was enormously increased by the introduction of power-operated pneumatic machines, including simultaneous jolt squeezing, each operation of the machine being controlled by a separate valve. Convenient placing of the valve-gear controls enabled production to be considerably speeded up, the necessary operations being set in strict rotation, so that the operator could use both hands and his right foot in the production of a mould. After jolting and squeezing the moulder exhausts the squeeze, swings the head clear and then depresses the pattern-draw valve, whereupon pins come up and strip the finished mould from the pattern. While the box is being stripped, pneumatic vibrators at the back of the table loosen the pattern from the mould. Handling boxes about 30 by 14 by 12 in., these machines are capable of producing up to 30 boxes per hour, depending very largely on the physical endurance of the operator. The maximum rate of production involves lifting 30 boxes an hour from an adjacent roller track and also removing the finished mould, which probably weighs at least 400 lb. Thus the operator has to be physically strong and by the end of the day he is sometimes quite fatigued.

Another disadvantage is that on one machine the operator might jolt for four seconds, whereas the man on the next machine might be jolting for seven seconds. Owing to the resultant variation of ramming densities there can be no real control over the quality of ramming and, ultimately, of the scrap produced.

As long ago as 1930 German industrialists were exploring the feasibility of reducing the number of operations, but it is believed that their projects never advanced beyond the experimental stage. After the war, Stone-Wallwork, Limited, approached the problem by removing all the valves from the machine itself and lining them up under a camshaft driven by a geared motor. The rotation of the camshaft depressed the poppets of the valves in the correct sequence, allowing air to travel to the appropriate operation of the machine. As the camshaft continued rotating the air was exhausted back to the cylinder. A machine of this type was exhibited at the Engineering & Marine Exhibition, 1947.

The advantages gained were considerable. The operator had only to put the moulding box on the machine, fill the box with sand, then simply depress a switch, whereupon the various operations followed automatically in the established sequence, including the movement of the swing-head over the machine table. The timing was so arranged that, after about three secs. of jolting, the swing-head came over the machine table as the squeeze cylinder started to rise. A few secs. later the squeeze cylinder was exhausted, the head swung back again to the clear position, and the lift pins came up and made the pattern draw. The completed mould remained on top of the four pins, for removal. After the operator had exhausted the pins by pressing the foot lever, he was ready for the next cycle of operations. The time taken from first pressing the push button to the completion of the mould was only 12 secs.

A number of machines of this type have been in production for three years and are giving very satisfactory service. The control box, however, was very expensive to produce, the cams being made adjustable in order to permit of variation in the times of jolting, squeezing, vibration, etc.

Recent Modifications

On the first two machines installed in the foundry of Henry Wallwork & Company, Limited, at Manchester, tests were made with different types of patterns and different sizes of boxes. It was found that the same operational times could be used for every type of job put on the machines, there being no necessity to provide longer jolting periods for the deeper boxes. The elimination of adjustable controls enabled a large saving in costs to be effected.

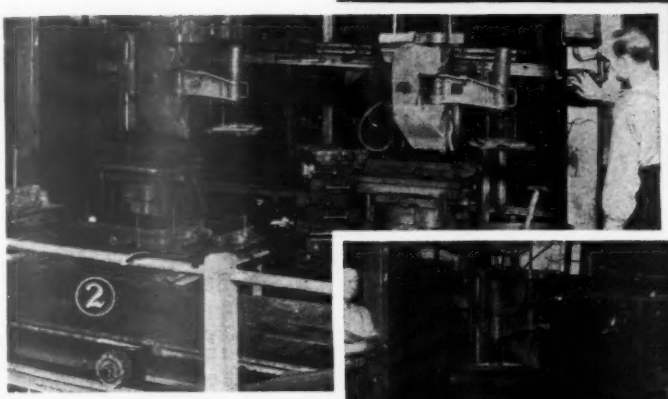
The second automatic unit designed was therefore a more simple machine, comprising a rotary sleeve valve and a geared motor driving a sleeve provided with a series of slots; the length of the slots being, of course, proportional to the time. The slots are spaced in an angular relationship to one another, so that the various operations follow in the correct sequence. As each slot passes over one of the holes provided in the body, air is allowed to flow to the appropriate port of the machine.

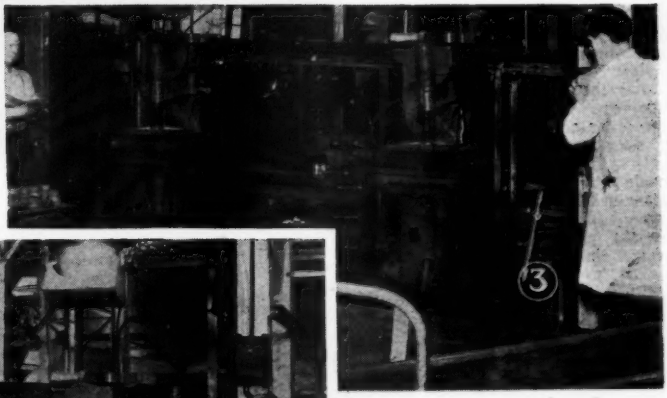
Sand Supplies

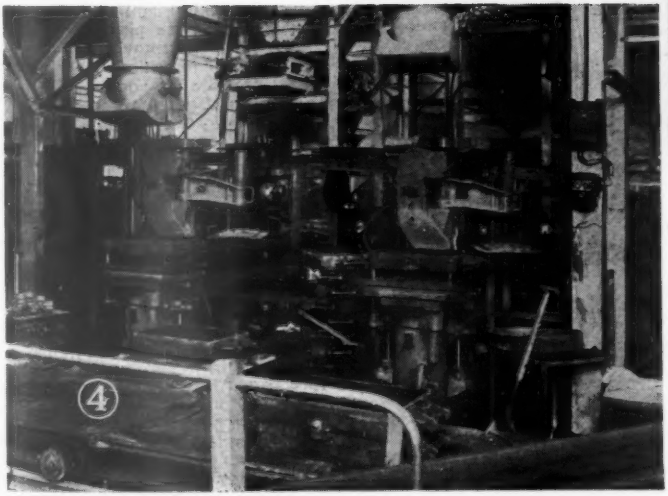
Much of the operator's hard work has now been done away with. Shovelling sand from the ground into the moulding box, however, is a back-breaking task, and the moulder may shovel as much as 30 or 40 tons of sand per day. Another step, therefore, was to put the sand into the moulding box for him. To overcome this problem, machines with "Automold" control units were first installed in foundries under "Duplex" gate hoppers. It was then decided to go one better by developing a rotary feeder-belt. By this arrangement an ordinary rubber belt running underneath an overhead hopper carries the sand over the moulding machine. The operator presses a button and the sand falls like rain into the moulding box. This operation can, of course, be combined with automatic moulding opera-

FIGS. 1-4.—STAGES IN THE SEQUENCE OF OPERATIONS FOR AUTOMATIC MOULDING WITH PUSH-BUTTON-CONTROLLED MACHINES.

(See below)







(1) Machines before commencement of operations.

(2) Single bottom half-mould on the short conveyor. Operator sets a new sequence in motion after filling the box parts with sand from the overhead hoppers.

(3) Machines in the "squeezing" position.

(4) Full view of the two machines showing the overhead sand hoppers. At this stage, the half-moulds on the pins have been made and raised in preparation for their removal to the closing position.

Automatic Moulding

tions. In this case, the moulder presses the push-button switch to operate the feeder belt; after the feeder-belt motor has rotated for a predetermined time, an electrical trip comes into action and starts the "Automold" sequence. Machines with automatic sand-feed systems are already in operation, but none with the combined sand-feed and "Automold" has so far been installed, though orders have been received from the Argentine, South Africa and Italy.

Operational Cycles

At the foundry of Dobson & Barlow, textile manufacturers, Bolton, one man operating two "Automolds" under "Duplex" gates is producing 120 boxes per hour and doing his own coring and closing. Fig. 1 shows the machine with the pattern plates assembled before commencing a series of operations. Fig. 4 shows the two machines side by side, one working on copes and the other on drags. At the commencement of a shift, a single bottom half-mould or drag is made and placed on the short section of roller track between the machines at right angles to the pallet conveyor. The operator then puts another pair of boxes on the machines and makes a top and bottom half-mould simultaneously.

FIG. 5.—REAR OF THE MOULDING MACHINES, OPERATOR PUSHES COMPLETED MOULD ON TO THE PALLET CONVEYOR AND LEAVES A BOTTOM PART FOR CORING-UP.

Fig. 2 shows the boxes filled with sand and the operator pressing the button. In Fig. 3, the machines are shown in the "squeezing" position (it will be noted that there is no-one in their vicinity), and in Fig. 4 the half-moulds have been made and the pins are raised, ready for their removing the boxes to the closing position. While the machines are in operation, the attendant places the cores in the previously-made bottom half, which has been left on the track. He then takes a newly-made cope half off the machine and places it on the cored-up bottom half. Next, he takes the second bottom half and lays it beside the cope, so that a bottom part for the next mould is available. Finally, he moves the finished mould to the pallet conveyor, also while the machine is engaged on the next cycle of operations. Moulds for spiral bevel gears, six in a box, are shown in production in Fig. 4; Fig. 5 shows the rear of the machines, and Fig. 6, a selection of castings made in this foundry, among which are the spiral bevel gears previously mentioned.

Two sizes of "Automolds" are in production: one to take boxes

(*Continued on page* 660.)

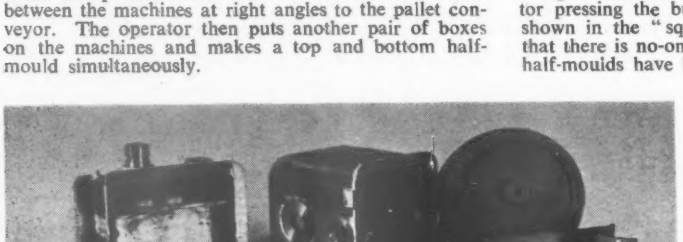


FIG. 6.—SELECTION OF CASTINGS MADE AT THE FOUNDRY OF DOBSON & BARLOW, LIMITED.

Guide to Aluminium Founding—IV

Moulding Practice for Aluminium-alloy Castings

By A. W. Brace, A.I.M.

(*Continued from page* 607.)

The moulding of all aluminium-alloy castings begins in the pattern shop, and some discussion of pattern requirements is necessary before considering actual moulding technique. Patterns in wood suffer from a tendency to warp after being in use for some time. In addition, mahogany and similar pattern wood is not easy to obtain. On the other hand, metal patterns, although requiring more time to prepare, have longer life and greater accuracy. Aluminium alloys for patterns combine lightness with good resistance to wear and ability to take a high finish. Patterns made mainly in aluminium alloy will be found to be economical, since hold-ups due to repair of pattern equipment will be almost eliminated. Implementation of this suggestion involves the installation of metal-shaping machinery, which may not be familiar equipment in some pattern shops. The initial expense may easily be repaid by the economy effected in pattern-maintenance costs as well as by a better finish and improved accuracy for the finished casting.

Portions of aluminium patterns on which heavy wear is expected are usually reinforced with brass or cast-iron inserts. Core boxes are frequently made of aluminium alloy, in part or whole; for some time it was thought that only cast iron would be satisfactory for core-blowing machines, but more recently aluminium alloys have been successfully employed. Other materials also find application for pattern work, among these being plaster of Paris, which can often be used to advantage in making large odd-sides, or in quickly preparing patterns where only small quantities of castings are involved.

When designing a pattern layout, attention should be paid to the possibilities of machine production for the moulds. Slight modifications to the design, for instance, so that deep pockets or undercuts are avoided, can effect substantial reductions in production costs. Generous radii to ensure a gradual transition from thick to thin sections assists feeding, as well as being advantageous in avoiding stress concentrations arising in the part in service. In normal practice, the pattern is mounted on a plate of appropriate size. Once a satisfactory technique has been established, the runners and risers should be included as an integral part of the pattern.

Moulding Machines

Moulding machines require no modification for aluminium alloys. They may be the simple draw type; draw-squeeze; squeeze-turnover-draw; or jolt-squeeze-turnover type. Many incorporate a vibration mechanism to assist pattern withdrawal. Each of the above types is of increasing complexity and cost, but these are compensated by the ability to cope with larger and more complex work. Aluminium alloys, and in some cases magnesium alloys, are being widely adopted for moulding boxes, thus reducing fatigue and handling time. Simple pattern-draw machines are limited in the capacity of sand and depth of pattern which they can take. When this operation is com-

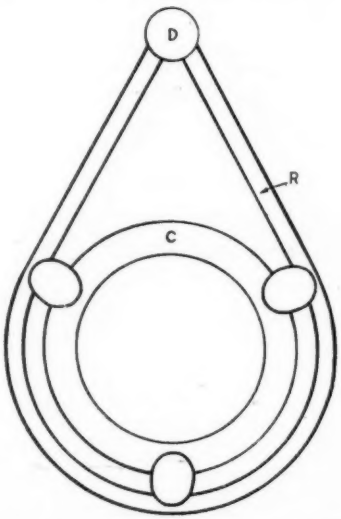


FIG. 1.—METHOD OF RUNNING A SMALL RING-SHAPED CASTING.

Guide to Aluminium Founding—IV

bined with a squeeze mechanism, much hand ramming can be eliminated, particularly that involved in backing the pattern face. The addition of a turnover mechanism enables deeper and more intricate patterns to be handled. Larger machines incorporate a jolting mechanism to ram the sand; these are suitable for jobs whose finished weight is in the order of 40 lb.

Gating Practice

The principles of mould design for aluminium-alloy castings are similar to those for most non-ferrous alloys. Briefly these are: (1) That the mould should be filled quietly from the bottom to top; (2) the metal should always be poured through a runner and never directly into the cavity; and (3) dimensions of sprue, runner and gates should be adjusted to give an even flow of metal, to avoid turbulence and to keep the pouring-cup full. There are little concrete data available on the relation between the cross-sectional area of runners and ingates; the few published accounts, indeed, give slightly divergent recommendations. A report of German practice states that, using a ratio of 1 : 3 : 5 for the relationships of sprue area : runner area : ingate area, satisfactory gating can be achieved.[1] A more recent French account gives the relationship as 1 : 1.5 : 2.[2] This is clearly of a rather different order to the former figures and this fact indicates the need for investigation into this fundamental aspect of mould design. Aluminium alloys are rather sluggish in flowing as compared with cast iron or bronze. Consequently, both runners and risers should be of generous dimensions. The rather long solidification range for many aluminium alloys means that heavy risers are necessary. The weight of risers and runners may be anything between one-third and two-thirds the weight of the metal cast.

Chills

Chills are used to produce sound sections where feeding is not practicable, and may also be used to influence the direction of solidification. They may be of soft cast iron, bronze or aluminium, but whatever the material they should be coated with a suitable wash to prevent adhesion to the molten metal. The suspension of red lead oxide in spirit, sometimes used in ironfoundries, is unsuitable for aluminium castings. Various proprietary washes are on the market which have been found to be satisfactory. They consist essentially of talc, China clay, or some similar refractory, bonded with bentonite substitute, molasses or organic gums depending upon whether they are water- or spirit-base mixtures. One mixture, claimed to be suitable, consists of 2 lb. white talc, 1 lb. whitening, 1 lb. molasses and water sufficient to bring to a creamy consistency.[3] In deciding the area and thickness of a chill to employ for a particular section, account should be taken of the relative thermal conductivities of the three materials:—Cast iron, 0.13; brass (70/30), 0.24; and aluminium (A.C.6), 0.40. Large chills should be vented by drilling holes in them at least $\frac{1}{16}$ in. dia. and one inch apart.

Examples of Running Methods

To illustrate the various running systems it is advisable to consider some typical types of components. A small ring, up to about 12 in. dia., such as that illustrated in Fig. 1 (in this and subsequent illustrations D is the downgate, R the runner, I the ingate, C the casting, and F the feeding head), with perhaps minor additions of lugs or a small flange would be run in the manner indicated. The method ensures an even entry of metal to all parts of the casting and avoids local overheating. If the basic design of the component is developed to make a cylinder some three inches or more in depth, as in Fig. 2, a ring runner will be placed at the first joint. Whether the runner is placed outside or inside the wall depends upon its dimensions and the size of the box available. A double-pour operation may be necessary for large-dia. components of $\frac{1}{2}$ cwt. or more cast weight. It should be noted that, for large cylindrically-shaped components, in addition to top risers, blind risers may be used to assist feeding some

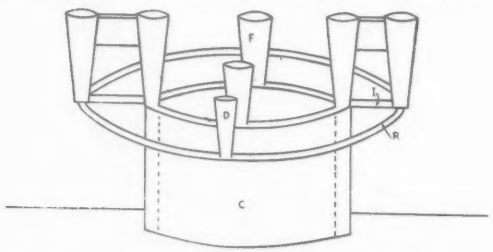


FIG. 2.—GATING AND FEEDING SYSTEM FOR A CYLINDRICAL CASTING.

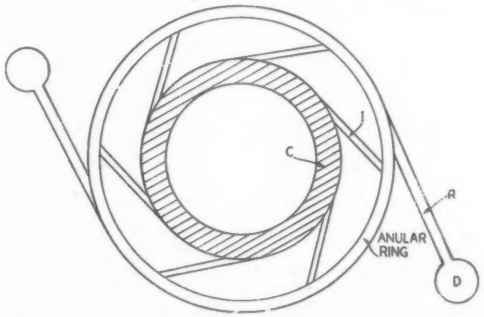


FIG. 3.—TWO-SPRUE METHOD FOR RUNNING A LARGE RING CASTING.

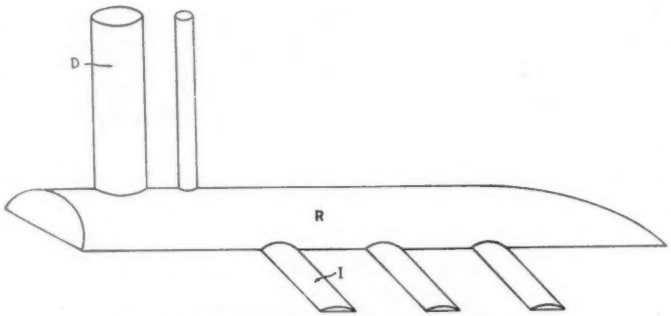


FIG. 4.—RUNNER USED FOR BOX-SHAPED CASTINGS.

of the lower sections. A further modification, sometimes used by aluminium foundries, is to connect the top of a riser which feeds the main body of the casting to one feeding its uppermost face so that an additional reservoir of liquid metal is available. In the case of components, such as radial-aero-engine blower-cases, which are essentially a shallow cylinder in shape with a base added, the whole bottom face may be chilled to ensure that solidification proceeds from the base. Chills are sometimes used on highly-stressed portions of castings not only to ensure soundness but to produce superior mechanical properties. The addition of bosses or lugs to the upper face usually calls for feeding by risers. When they are on the base of a casting, chills are usually employed. Large rings of simple section may be run by the method shown in Fig. 3; in this case a double pour has been arranged. The incorporation of tangential ingates assists the elimination of impurities and the smoothing out of turbulence.

Other General Types

A further general classification into which castings fall is the "box" type. Runners for these follow the lines indicated in Fig. 4. The "tailing" out of them is a normal feature of aluminium moulding practice since it ensures that any impurities carried with the first rush of metal will not pass through the gate into the casting. Some very large castings may require gating at the first and second box joints to ensure proper distribution of heat in the mould. With a deep casting, improperly placed gates could result either in turbulence, if placed too high, or in cold metal in the risers if at too low a point. Thin-section castings may give some difficulty from being "short run" or showing blow-holes or oxide due to turbulence produced in filling the mould. To prevent this, a box-and-plug sprue is often used (Fig. 5). In this case, the box is filled with metal while the plug is maintained over the inlet. When the box is nearly full, the plug is quickly removed and a smooth but rapid pour is maintained. The ingate may take the form of a slit along the length or height of a casting; this ensures rapid filling of the mould and the elimination of turbulence.

(A final article on "Moulding and Core Sands" will conclude this series.)

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[2] "The French Foundry Scene." *Revue de l'Aluminium*. 146.
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[5] "Plaster, Plastus and Low-melting-point Metals in Patternmaking. H. Plucknett. XXXVIII B 64-8 Proc. Inst. of Brit. Foundrymen.
[6] "Recommended Dimensions for Aluminium Castings." Production Eng., 234, 1943, *14*.
[7] "Recommended Practices for the Sand Casting of Non-ferrous Alloys." American Foundrymen's Association, pp. 99-106.

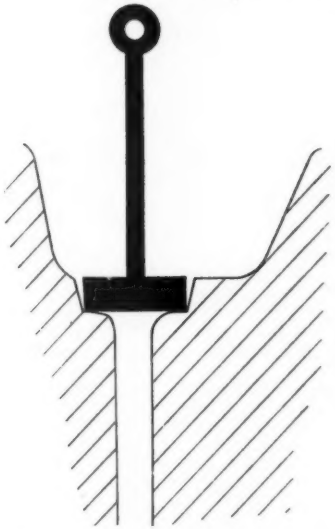

FIG. 5.—BOX-AND-PLUG TYPE SPRUE FOR ENSURING SMOOTH ENTRY OF METAL INTO RUNNERS.

MR. H. V. LUSH, president of Metal Stampings, Limited, Toronto, is at present on a short visit to the United Kingdom. He hopes to purchase certain lines of aluminium ware which are not at present being produced in Canada. In addition, he will be interested in enamelware, cutlery, stainless-steel ware, tinware, etc. He intends only to buy direct from manufacturers, preferably from those who are not already represented in the Canadian market, and may be contacted at the Savoy Hotel, Strand, London, W.C.2.

Luncheon

Mr. C. C. Booth, J.P.

Mr. C. C. Booth, J.P., gave a luncheon party last Monday at a West-end club in honour of the Master of the Founders' Company (Mr. A. P. L. Blaxter). Among the guests were Mr. J. Shaw, Mr. Wilson Wiley, Mr. D. G. Bissett, Dr. J. G. Pearce, Mr. W. J. Fossick, Mr. H. W. Wright, Mr. H. B. Drew, and Mr. V. C. Faulkner, who presided in the unavoidable absence of the host through indisposition.

Dinner

Mr. Malcolm J. Glenny

Mr. Malcolm J. Glenny, chairman, South of England Ironfounders' Association, gave a dinner party at the Tallow Chandlers' Hall on Wednesday of last week to enable the members to meet some of the officers of the national ironfounding organisations. Among the guests present were:—Mr. N. P. Newman, J.P., Mr. D. Graham Bissett, Mr. R. B. Templeton, Mr. J. J. Sheehan, M.Sc., Mr. S. H. Russell, Mr. Vivian Elkington, Mr. F. H. Seager, Mr. C. A. M. Gray, Dr. J. G. Pearce, Mr. D. Howard Wood, Mr. C. Gresty, Mr. F. Arnold Wilson, Mr. C. C. Booth, J.P., Mr. R. Forbes Baird, Mr. Kenneth Marshall, Mr. G. B. Judd, Mr. V. C. Faulkner, Mr. H. Scott, Mr. H. V. Shelton, and Mr. R. S. Barrie.

Automatic Moulding

(*Continued from page* 656.)

up to 18 by 24 in., and the other from 28 in. by 34 in. A number of machines have been ordered, many for overseas.

These new machines represent a distinct step forward in the elimination of manual labour, but the operator still has to lift the moulding box on to the machine and take it off again. However, the company are now engaged on another development, still in the design stage, whereby the boxes will be lifted mechanically on to and off the machine. They will then have reached a point where the empty box is lifted on to the machine, the sand is fed into the mould and, after moulding, the finished box is pushed away.

The elimination of the human factor should ensure that every mould is exactly the same and that the density of ramming is always uniform. Not only will production be speeded-up to figures which formerly would have seemed fantastic, but heavy boxes will be handled even by women operators without effort. More still remains; the "Automold" system is next being applied as a turn-over-draw machine. Once this has been achieved, it can be said that British industry has really succeeded in mechanising machine moulding, instead of merely introducing a number of mechanical devices to assist the moulder.

Book Review

Radio Frequency Heating. By L. Hartshorn, D.Sc. Published by George Allen & Unwin, Limited, Ruskin House, 40, Museum Street, London, W.C.1. Price 21s.

Considerable progress has been made in the use of electricity of very high frequencies for industrial purposes in recent years, and the possible applications to foundry work need to be carefully examined if the industry is to take full advantage of scientific advancement in this direction.

Dr. Hartshorn's new book deals with the two specific forms of radio-frequency heating, induction heating of metals, and dielectric heating of non-conductors. It is fairly well known that, in applying the latter method to the baking of cores, the heating time can be reduced from an hour or more to something in the order of five minutes. It is not, perhaps, so well realised that cast iron responds satisfactorily to high-frequency induction hardening.

The book under review covers the theory and practical applications of radio-frequency heating, and although foundry materials are not specifically mentioned, the information is developed from basic principles, and is sufficiently general for the possible applications to the foundry industry to be appreciated. The references provide a bibliography on the subject which introduces the reader to the extensive literature available. The theoretical considerations assume a knowledge of electricity, and higher mathematics beyond that of the average practical foundryman, but many technicians in the industry will find this work of great value.

E. C. D.

British Standards Institution

The British Standards Institution Monthly Information Sheet for October, lists under "New Standards Issued": 1000 (669): 1949 Metallurgy. (10s.), one of the series of sectional parts of the Universal Decimal Classification, this 44-page document contains the full schedules for 669 (Metallurgy), together with a detailed alphabetical subject index; 1121: methods for the analysis of iron and steel; Part 12: Silicon in acid-resisting high-silicon iron. (1s.), part 13: 1949 chromium in iron and steel, (1s.), part 14: 1949 copper in carbon and low-alloy steels. (1s.): and 1591: 1949 acid-resisting high-silicon iron castings. (2s.). Under "Standards Withdrawn" there are:—361; 1929 7 per cent. copper/aluminium-alloy castings for general engineering purposes; 362: 1929 12 per cent. copper/aluminium-alloy castings for general engineering purposes; 363: 1929 Zinc/copper/aluminium-alloy castings (suitable for crank cases and general use); 702: 1936 silicon/aluminium-alloy castings for general engineering purposes; 703: 1936 Y-alloy castings (as cast) for general engineering purposes, and 704: 1936 Y-alloy castings (heat treated) for general engineering purposes. The above eight standards are now covered by the new standard B.S. 1940: 1949 aluminium and aluminium-alloy ingots and castings for general engineering purposes.

Factors Affecting the Colour of Titanium Enamels*

Results of Practical Experiments

By N. S. C. Millar

Over the past forty years, since the use of aluminium oxide in vitreous enamels became a commercial possibility, its tendency to cause cream discoloration in white enamels has been adversely commented upon. Indeed, as long ago as 1909, a German patent was taken out by Hillringhaus and Heilman[1] on the use of small quantities of cobalt to correct the yellowness.

During the past ten years the use of titanium oxide as an opacifier has developed very rapidly and the problem of preventing this cream discoloration has been the subject of many investigations subsequently reported in the technical Press. Of the suggestions which have been put forward to explain it, the majority are based on the assumption that the presence of some impurity, either in the fritted materials or in the mill additions, is responsible.

In this Paper it is intended to review the Papers so far published, and then to describe recent work carried out in the ceramic laboratory of British Titan Products Company, Limited, which throws a new light on the problem.

Effect of Coloured Compounds Present as Impurities

(1) *Iron Oxide*

Perhaps the principal impurity which has been held responsible for the cream coloration of white titanium enamels is iron in some form or another.

It is well nigh impossible to obtain an enamel absolutely free from iron when one considers that most of the naturally occurring minerals used in frit making, such as felspar, quartz, cryolite, clay, etc., all contain a certain amount. The bricks used in the construction of the smelter also contain iron as impurity, some of which may be leached out by the molten frit.

Many references to the effect of iron oxide on colour exist in enamelling literature. In 1909 Vondracek[2] found that if sufficient titanium oxide was added to an enamel, an opaque, yellow glass was obtained on reheating. He suggested that this yellow colour was due primarily to iron impurities. Dutzel and Boncke[3] assumed that the yellow colour of titanium glasses was caused by an $FeO\text{-}TiO_2$ complex. Beyersdorfer[4] also thought that this $FeO\text{-}TiO_2$ complex was one of the causes of cream discolorations found with titanium-containing glasses. Other exponents of this idea were Aldinger[5] and Tinsley.[6] Perhaps the best account of the effect of iron oxide on titanium enamels is that given by Tickle[7] in a Paper presented to the I.V.E. at Chester in March, 1946. Summarising this Paper, he found that the effect of iron compounds in the frit was totally different from that obtained when iron oxide was added at the mill. When present in the frit, iron acts as a network former and the general appearance of the fired biscuit is a very cream colour of low brightness. When, on the other hand, iron oxide is added at the mill, it acts as a network modifier, *i.e.*, it forms cations which fill some of the positions or interstices in the silica network. In such surroundings the ferric iron is practically colourless (faint pink) and the resulting fired enamel has a greatly increased brightness value with only a slight cream cast.

(2) *Chromium Oxide*

It is thought, particularly by American workers, that chromium impurities are the prime cause of the cream colour of titanium enamels. This is very feasible, as it is well known that small amounts of chromic oxide at the mill will colour enamels considerably. A mill addition of 0.01 per cent. Cr_2O_3 will raise the colour index of an enamel from 12.5 to 19.8, while an 0.05 per cent. addition increases the colour index to 34.[7]

(Colour index is an arbitrary figure used to denote the tone of an enamel or the deviation from neutral white. It is determined by measuring the percentage brightness of the fired enamel in red, blue and green light, using an integrating sphere photometer, then subtracting the percentage brightness in blue light from that in red light, dividing by the percentage brightness in green light and multiplying by 100. A zero figure denotes a neutral white; a negative value denotes a blue or green tone, and a positive value denotes a red or cream tone, the size of the value signifying the intensity of the tone.)

Vondracek[2] quoted chromium as being a possible cause for the discoloration. Friedberg, Petersen and Andrews[8] in America also stated that chromium is the real culprit and found that small amounts of Cr_2O_3 in a

* Paper presented at the Annual Conference of the Institute of Vitreous Enamellers, in Birmingham, October, 1949.

Colour of Titanium Enamels

TiO_2 enamel composition cause a definite cream colour, whereas relatively large percentages of Fe_2O_3 cause no appreciable colour change.

Marbaker, Saunders and Baumer,[9] in a Paper describing the effects of various clays used in mill additions on the properties of a titania-opacified enamel, agree with the assumption that chromic oxide is responsible for this cream discoloration. They also state that the colour of the fired enamel depends upon the clay in the mill, but were unable to show that the chemical composition or the physical condition of the clay had any predictable effect on the properties of the enamel.

(3) *Gallium Oxide*

Gallium compounds appear to act in the same way as do those of chromium. A mill addition of 0.007 per cent. gallium sesquioxide increased the colour index of an enamel from 6 to 8.4 and a further 0.011 per cent. addition raised this figure to 12.4.[7]

(4) *Rhodium Oxide*

Rhodium sesquioxide also discolours titanium enamels,[7] but to a less extent than gallium. An 0.1 per cent. mill addition raised the colour index of fired titanium enamel by 9.

(5) *Vanadium*

It is most probable that minute amounts of this element have a profound effect on the colour of titanium self-opacified enamels. This element can be introduced into the frit from certain types of fuel oil used in oil-fired smelters, which is a point that should not be overlooked.

Effect of Reduction of TiO_2

Reduction of TiO_2 to a lower oxide has been suggested as a cause of the yellow coloration experienced with titanium-opacified enamels. This idea was put forward by Vondracek[2] as well as Friedberg, Petersen and Andrews.[8] Sheen and Turner,[10] interested in preparing colourless titanium-bearing glasses from relatively pure constituents, found the yellow colour to be entirely due to reduction of the TiO_2.

Effect of Batch Composition

It is a well-known fact that the colour of white titanium-opacified enamels can be varied by altering the batch composition. Examples of this are as follow:—

(*a*) An increase in the alkali content will throw the colour of the fired enamel over to the cream side, although partial replacement of soda by potassium will cause a more neutral or less cream colour.

(*b*) An increase in silica content results in whiter fired enamels, *i.e.*, high silica favours a white having a slight blue tone.

(*c*) Increasing the alumina content of the frit acts in a similar way to silica, but to a lesser degree.

(*d*) Small amounts of combined antimony or calcium confer greenish casts on the colour of the fired enamel.

The influence of batch composition on the colour of titanium enamels is further discussed later in this Paper.

Effect of Crystalline Form of Titanium Oxide

That the cream coloration often associated with titanium enamels is to some extent due to the presence of impurities such as iron, chromium, etc., is not disputed, but a more important cause is to be found in the crystal structure of the TiO_2 which crystallises out in the firing process. If the recrystallised TiO_2 is in the rutile form, the resultant enamel will be cream, but if conditions are such that anatase crystallises out, a cold neutral white is obtained.

Friedberg, Petersen and Andrews,[8] in a Paper describing the effect of composition on properties of titanium enamels, found that the opacifying crystals in these titanium enamels were either anatase or rutile, the majority being in the rutile crystal modification. They stated that the effect of composition of the frit on the form of TiO_2 which recrystallised on firing was not definite. They did determine the fact that the crystal form of TiO_2 added at the smelter does not control the form of TiO_2 recrystallising. In a later Paper, Friedberg, Fischer and Petersen[11] described the effect of TiO_2 crystals on the spectrophotometric properties of titanium-bearing enamels and showed that increased firing decreased the anatase, and increased the rutile content, and the colour changed from a blue-white to a cream-white. They also stated that the change in colour was related to the scattering of blue light by small particles at lower temperatures or shorter firing times. They concluded that "... the spectrophotometric properties of titanium enamels are determined mainly by the particle size of the opacifier. Minimising the colour variations entails controlling the particle size regardless of whether the particles are anatase or rutile or both."

Karl Kautz[12] in his classic account of the use of molybdenum in enamels wrote, "If TiO_2 could be stabilised in the anatase form so that firing temperatures up to 1,500 deg. F. (815 deg. C.) could be used, this method (*i.e.*, of controlling colour) would be quite promising." This Paper gives an account of such a method.

Crystal Forms of TiO_2

Titanium oxide can exist in three different crystalline forms, namely, rutile, anatase and brookite. Brookite is very unstable, and is of no commercial value. When anatase is heated to 800 to 850 deg. C. it is converted into the rutile form, the actual transition temperature varying with the impurities present. The word "rutile," as used in this Paper, refers to one of the three crystal forms of titanium oxide and is not to be confused with naturally-occurring rutile.

The anatase crystal structure of TiO_2 consists of ions of titanium and oxygen, closely bonded, and does not readily permit the penetration of light, thus partly accounting for its high refractive index and hence its remarkably strong opacifying power. The rutile structure is even more compact than that of anatase and has a still higher refractive index. In spite of this greater opacifying power of rutile its basic colour is thought to be cream, whereas that of anatase is more neutral. It is certainly more sensitive

to the effect of colouring oxides. Some of the properties of rutile and anatase TiO_2 are given in Table I.

Whether titanium oxide is present in the frit or fired enamel in the anatase or rutile crystalline form can readily be determined by X-ray methods.

X-ray Examination of Frits and Fired Panels

When a finely-powdered specimen is irradiated with an X-ray beam. the beam is reflected only at certain angles and these angles are characteristic of the crystalline species of the powder. The reflected

TABLE I.—*Some Properties of Rutile and Anatase*

—	Rutile.	Anatase.
Specific gravity	4.2	3.9
Melting point	1,825° C.	Indefinite (transition to rutile)
Moh's hardness	6–7	5.5–6
Refractive index	2.7	2.55

rays are made to register on a strip of film and the result is the conventional X-ray powder photograph. Every distinct crystalline material has its own unique pattern. The pattern depends on the internal structure and arrangement of the atoms so that different crystalline modifications of the same substance, *e.g.*, anatase and rutile, give entirely different X-ray patterns.

When examining a frit the specimen is ground very finely, then subjected to a beam of X-rays. If the frit is "batch-free" there will be no crystalline material present and the resulting photograph will show no characteristic lines.

In the case of a fired enamel powdering is unnecessary as the flat enamel surface is sufficient to reflect an X-ray beam to give a distinct pattern.

Fig. 1 shows the pattern obtained from: (A) 100 per cent anatase TiO_2; (B) 70 per cent. rutile TiO_2. 30 per cent. anatase TiO_2; (C) 100 per cent. rutile TiO_2; (D) (i) a "batch-free" frit, (ii) a frit containing undissolved TiO_2; (E) (i) a fired enamel opacified by 100 per cent. anatase TiO_2, (ii) a fired enamel opacified by 60 per cent. anatase, 40 per cent. rutile TiO_2; (iii) a fired enamel opacified by 100 per cent. rutile TiO_2.

It is obvious that such photographs afford an easy means of identifying the crystalline forms of titanium dioxide. Moreover, by choosing two lines. one from each of the patterns characteristic of rutile and anatase, and measuring the intensity ratio, the percentage composition of a rutile/anatase mixture can be readily determined. In practice, a set of standard photographs of specially-prepared mixtures of rutile and anatase is used for visual comparison with the photographs of the specimen under examination. The photographs illustrated in Fig. 1 (D and E) are taken with a special camera which reduces the time resuired for examining a large number of specimens, yet retains a sufficient portion of the photograph for the crystalline modification of the TiO_2 to be determined.

Blue-whites Due to Rayleigh Scattering Effect

Although, as previously stated, the basic colour of rutile is thought to be slightly cream, very small particles of both rutile and anatase will appear blue, due to the Rayleigh scattering effect. An enamel having a blue-white colour dependent on Rayleigh scattering would be of no commercial use whatsoever, owing to the very strict time/temperature conditions which would have to be employed during the firing operation. Also, touching up of small defects would be impossible because the TiO_2 crystals in the first fire enamel would grow and consequently lose their blue appearance during the firing of the enamel applied to cover the defect.

Blue-whites Due to Reduction of TiO_2

Blue-white enamels can be obtained when a titanium self-opacified frit is smelted in a reducing atmosphere. On firing such a frit quite deep blue specks can be seen, which disappear on prolonged firing in an oxidising atmosphere. Ware enamelled with frits smelted in reducing atmospheres appear to have a cold neutral colour due to these small blue-black particles, but the brightness is quite low, for obvious reasons. This "blue-specking" defect can also appear if the batch is not thoroughly mixed, although it can be alleviated by the use of a "granular" titanium oxide.

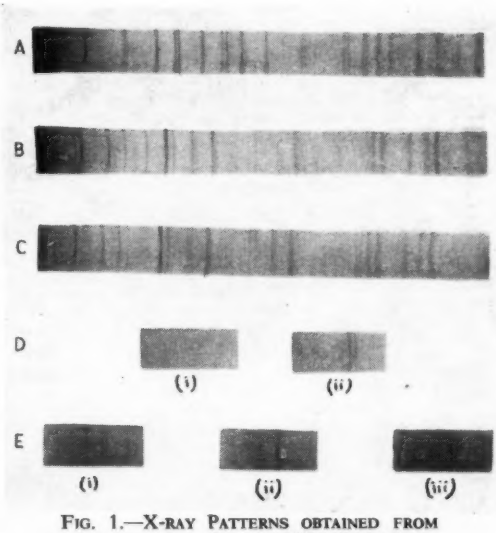

FIG. 1.—X-RAY PATTERNS OBTAINED FROM ANATASE AND RUTILE TiO_2 SPECIMENS.

TABLE II.—*Effect of Temperature and Time on Anatase Production*

Smelting temp. deg. C.	Smelting time (mins.).	Amount of rutile present in quenched frit.	Amount of anatase present in quenched frit.	Percentage anatase in sample fired for 3 mins. at		
				700° C.	750° C.	800° C.
1,200	50, under-smelted ..	Considerable	Nil	60	60	30
1,200	67, correctly smelted ..	Very slight	Nil	97	80	50
1,200	84, over-smelted ..	Nil	Nil	100	90	65
1,100	36, under-smelted ..	Considerable	Nil	80	60	35
1,100	74, correctly smelted ..	Some	Nil	80	70	45
1,100	99, over-smelted ..	Slight	Nil	90	80	45

This type of blueness is due to reduction of the titanium oxide, or more strictly speaking, to an oxygen deficiency in the TiO_2 crystal lattice. On firing this type of frit in an oxidising atmosphere, the blue specks which are at first apparent disappear, leaving a homogeneous white colour, as the titanium oxide regains its complete oxygen content from the air. Whenever this oxygen-deficient TiO_2 is reoxidised the resultant crystal structure is always that of rutile, and never anatase.

The colour of a high-titanium frit which has been smelted under reducing conditions is dark brown, sometimes almost black. It must be understood that, expressed as a weight percentage, this oxygen deficiency in the titanium oxide is only slight, even though the dark colour indicates a radical change in the crystal structure. An X-ray photograph of the dark-coloured TiO_2 still shows the rutile pattern, which means that the crystal lattice is that of rutile except that a few of the positions normally occupied by oxygen are vacant. The structure remains basically the same as oxygen is removed until a critical titanium/oxygen ratio is reached. At this point, the lattice collapses and takes up a more stable structure, *e.g.*, that of TiO_2. The conditions required to bring about this crystal lattice change of TiO_2 are much more severe than are likely to obtain during the smelting of an enamel.

Conditions of Smelting to Obtain Anatase Opacified Enamels

To obtain enamels of good colour which are stable to firing conditions, the first essential is, therefore, that the smelting be carried out under oxidising conditions. To obtain such an atmosphere the gas/air or oil/air ratio of the furnace burners must be so adjusted that combustion is complete. Some rotary oil smelters are fitted with a counter blast, which is a very efficient means of ensuring an oxidising atmosphere. If some of the alkali in the raw batch is added as nitrate instead of the more usual carbonate, this also will help to maintain oxidising conditions.

To determine the optimum smelting conditions, *i.e.*, those which will produce frits firing out to give anatase TiO_2, 1,000 gm. batches of a super-opaque enamel containing 18 per cent. TiO_2 were smelted in fireclay crucibles at different temperatures. The crucible was not "topped up" during each smelt. During each smelt the frit was poured when, (*a*) under-smelted, (*b*) correctly smelted, *i.e.*, a thread of enamel was visibly free from undissolved batch, and (*c*) over-smelted. Small amounts of these frits were ground and examined by X-ray methods for "batch-freeness."

Small samples of each of the frits were fired for three minutes at 700, 750 and 800 deg. C., and the resulting enamels examined for anatase/rutile ratio in the TiO_2, which had recrystallised. The results are given in Table II.

From these results it is apparent that any undissolved TiO_2 in the frit is present as rutile, which is only to be expected at these elevated temperatures. It is also apparent that any particles of undissolved rutile act as nuclei, or centres, for the crystal growth of the TiO_2 which crystallises out during the firing operation and thus depress the proportion of anatase in the fired enamel.

A further conclusion to be drawn from the results expressed in Table II is that a frit which looks batch-free by visual examination of a thread of enamel withdrawn from the melter, may actually contain a small amount of undissolved TiO_2, and further smelting is necessary to dissolve this last trace. This situation may be aggravated by poor mixing of the raw batch, leading to local high concentrations of TiO_2.

Another cause of residual titanium oxide in the frit may be due to inefficient quenching, leading to slow cooling of some portions of the frit. These conditions are favourable for premature recrystallisation of the

TABLE III.—*Effect of Delayed Quenching on Anatase Production*

Smelting temp. deg C.	Smelting time (mins.).	Rutile present in quenched frit.	Percentage anatase in sample fired for 3 mins. at		
			700° C.	750° C.	800° C.
1,150	55 (correctly smelted)	Nil	100	100	80
1,150	Above cooled and held at 1,050° C. for 15 mins.	Marked amount ..	90	70	45

TiO_2, and since the temperature is high, this TiO_2 will be in the rutile form.

This was demonstrated in two simple experiments. In the first, a sample of really batch-free frit was allowed to cool slowly from 1,150 deg. C. to room temperature. The TiO_2 which recrystallised was all in the rutile form.

In the second experiment, the same batch composition was correctly smelted at 1,150 deg. C. and part poured into water. The remainder was cooled to 1,050 deg. C. and held for 15 minutes before pouring. The anatase/rutile ratios obtained on firing these frits are shown in Table III.

It may be concluded that if a high proportion of anatase TiO_2 is desired in the fired enamel, particular attention must be paid to genuine "batch-freeness," efficient mixing of the raw batch and rapid quenching of the melt, all of which tend to give a product in which the TiO_2 is truly in solution and which contains few or no rutile nuclei.

Effect of Firing Temperature and Time on Anatase Content

A number of frits of differing compositions were smelted and then fired over a range of temperatures from 700 to 800 deg. C. for three minutes in an electric muffle furnace. In every case X-ray examination showed that it was possible to recrystallise anatase TiO_2 provided the firing temperature was not too high and the firing period was not too prolonged.

These results are exactly paralleled by those reported by Friedberg, Fischer and Petersen.[11] As the firing temperature is raised or the firing time prolonged, the proportion of rutile to anatase increases. This proportion is more sensitive to temperature than to time.

The following examples illustrate these conclusions:

Frit 1—fired 4 minutes at 840 deg. C. contains 30 per cent. anatase.

Frit 1—fired 6 minutes at 840 deg. C. contains 20 per cent. anatase.

Frit 2—fired 4 minutes at 780 deg. C. contains 100 per cent. anatase.

Frit 2—fired 4 minutes at 840 deg. C. contains 85 per cent. anatase.

TABLE IV.—*Composition of Frit* 1,135.

Batch composition.		Calculated melted composition.	
Borax (hydrated) ..	28.9	TiO_2	17.1
Quartz	45.7	SiO_2	57.1
Potassium nitrate ..	9.8	Na_2O	5.9
Magnesium carbonate ..	1.9	K_2O	5.6
Titanium oxide ..	13.7	B_2O_3	13.2
		MgO	1.1
	100.0		100.0

Mill additions.

A. Frit 1,135 ..	100 pts.	C. Frit 1,135 ..	100 pts.
Pipe clay ..	5 pts.	Pipe clay ..	3 pts.
		Bentonite ..	½ pt.
B. Frit 1,135 ..	100 pts.	TiO_2	1 pt.
Pipe clay ..	5 pts.		
TiO_2	1 pt.		

The electrolyte used to flocculate the clay can be ammonium carbonate, borax, sodium nitrate, etc.

TABLE V.—*Effect of Mill Additions on Brightness and Colour Index of Standard Panels.*

Mill addition.	Fired 4 mins. at 800° C.		Fired 4 mins. at 850° F.	
	Brightness per cent.	Colour index.	Brightness per cent.	Colour index.
5 per cent. clay ..	77	−10.3	79.1	−6.9
5 per cent. clay .. / 1 per cent. TiO_2 ..	78.1	− 8.6	80.4	−3.9

It should be noted that the possible range of firing temperatures is limited at lower temperatures by adverse effects of high viscosity on nucleation and crystal growth, and at higher temperatures by the increased solubility of the TiO_2 in the frit. Thus, it is apparent that TiO_2 can always recrystallise as anatase if the firing temperature is sufficiently low, but one must bear in mind the practical aspect of very slow nucleation and crystallisation rates which would necessitate impossibly long firing times.

The system of TiO_2 opacification may be regarded from a simple thermodynamic point of view. The TiO_2 will tend, under the circumstances of extreme supersaturation as found in high-titanium enamels, to recrystallise as anatase. If the glass matrix is nucleated by rutile the anatase will transform to rutile because of the difference in solubility (anatase being the less stable, more soluble form). The transformation will take place most readily in regions well nucleated by rutile. In regions free of rutile there will be no transformation because of the high viscosity of the system. In a frit entirely free of rutile seeds, no transformation would be expected, except at high firing temperatures where direct conversion occurs without the intermediate solution of the crystals. Hence the great importance of smelting titanium self-opacified enamels until they are completely batch-free.

From this experimental work it is apparent that to obtain good-coloured enamels opacified by TiO_2 in the anatase form, the following conditions must obtain:—

1. The raw batch must be well mixed.

2. The smelting should be carried out under non-reducing conditions and the smelting must continue until the smelt is absolutely batch-free. Visual inspection is not always sufficient to decide this, so the smelting conditions should be established initially by X-ray methods and/or the enamel results, and, provided the batches are efficiently mixed, a strict time/temperature schedule can be applied to any one formulation.

3. The quenching of the frit should be carried out efficiently and rapidly to prevent slow cooling by slow pouring, or formation of large lumps. The higher the temperature at which the smelting is carried out, the lower will be the viscosity of the molten frit and hence, the more rapid will be the quenching.

4. The firing time and temperature should be kept at a minimum; the actual conditions depending upon the particular frit used. Oxidising conditions must prevail in the muffle.

5. The effect of any change in the composition of a frit should be considered in terms of the smelting temperature and time, the viscosity of the frit, and its

Colour of Titanium Enamels

effects on crystallisation characteristics. It should also be borne in mind that a second crystalline phase other than TiO_2 may crystallise out with a considerable effect on the product.

An enamel which under normal conditions is opacified by 100 per cent. anatase TiO_2 is frit 1,135 (Table IV).

Frit 1,135 can be smelted at 1,200 deg. C. to give a pale amber-coloured frit. When ground with mill additions A and B, sprayed on to normal blue-black ground-coated 3 in. by 2 in. steel panels to give an application weight of 24 gm. per sq. ft., then fired for four minutes at 800 and 850 deg. C., all four panels were opacified by 100 per cent. anatase TiO_2. Table V gives the percentage total brightness and colour index of each of these four panels.

From Table V it is apparent that all the panels have a blue-white tone as signified by the negative sign in the colour index.

The spectrophotometric curve (General Electric Recording Spectrophotometer) of frit 1,135 milled with 5 per cent. clay, 1 per cent. TiO_2 and fired at 830 deg. C., is shown in Fig. 2.

To find the firing range of frit 1,135 yielding the maximum anatase content, the frit was milled with 5 per cent. pipe clay and the slip sprayed on to ground-coated 3-in. by 2-in. steel panels to give an application weight of 24 gm. per sq. ft. Half of these panels were fired at 850 deg. C. for increasing times, and the other half were fired for four minutes at increasing temperatures. The percentage anatase was determined on each panel. These results are shown in Table VI.

From Table VI it is apparent that the change in colour of the enamel due to increasing the firing time is much less than the change in colour caused by elevated firing temperatures. This is explained by the fact that, as the temperature increases, so the viscosity decreases and hence the transformation of anatase to rutile is facilitated. Also, as the temperature increases, more anatase is converted directly into the rutile form without the intermediate solution of the crystals.

On prolonged firing, crystals of anatase TiO_2 grow

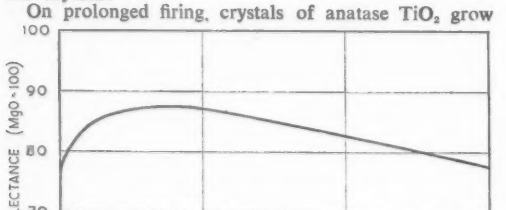

FIG. 2.—SPECTROPHOTOMETRIC CURVE FOR FRIT 1,135.

TABLE VI.—*Firing Range of Frit* 1,135.

Firing temp. deg. C.	Firing time (mins.).	Per cent. anatase.	Per cent. rutile.	Colour index.
850	4	100	0	− 4.1
850	6	100	0	− 1.2
850	8	100	0	0
850	10	100	0	+ 1.2
850	15	80	20	+ 2.4
800	4	100	0	− 7.5
850	4	100	0	− 4.1
880	4	85	15	− 0.6
900	4	60	40	+ 8.8
950	4	10	90	+24.8

5 per cent. pipe clay was added at the mill in each case.

at a very much slower rate than do crystals of rutile TiO_2. Consequently, the stability of anatase-opacified enamels, as indicated by colour change on repeated firing, is greatly superior to rutile enamels. This is a very desirable property when dealing with enamelled ware which must be resprayed and refired to cover a defect in the first coat.

Difference Between Anatase and Rutile Opacified Enamels Milled with Ceramic Colours

Frit 1,135 (anatase-opacified) and a frit which, when fired at 830 deg. C., is opacified by 100 per cent. rutile, were milled with 5 per cent. clay and 3 or 5 per cent. of several commercial ceramic colours. These slips were sprayed on to ground-coated 3-in. by 2-in. steel panels to an application weight of 24 gm. per sq. ft., then fired for 4, 6 and 10 min. at 830 deg. C. These firing times were chosen to exaggerate the differences in colour.

With each colour used the difference between the 4-, 6- and 10-min. fires was least with the anatase-opacified enamel.

Effect of Altering Batch Constituents on Anatase Content of Fired Enamels

Taking frit 1,135 as the basic formula, the effects of slight modifications to its composition were studied systematically. All the modified frits were smelted at 1,200 deg. C., ground with 5 per cent. pipe-clay and water, "set-up" with ammonium carbonate and sprayed on to ground-coated panels, again to an application weight of 24 gm. per sq. ft. Each slip was fired for 4 min. at 840 deg. C. and 5 min. at 890 deg. C. and the resulting enamel examined by X-ray methods for anatase/rutile content. From this series the following results were obtained:—

(*a*) A decrease in the TiO_2 or SiO_2 contents causes a decrease in anatase content, the same effect being produced by increasing the Na_2O and K_2O contents, or by introducing Li_2O.

(*b*) Varying the B_2O_3 content seemed to have no effect on the crystal form of the recrystallised TiO_2.

(*c*) A decrease in magnesium oxide causes a slight decrease in anatase content, but when the MgO was

replaced by the same amount of ZnO, there was no change in the TiO_2 structure in the fired enamel.

(*d*) Increase in the alumina content of frit 1,135 causes no diminution of anatase TiO_2.

The general conclusion which can be drawn from this series of trials is that an increase in alkalis, or a decrease in SiO_2, causes a lower percentage of anatase to crystallise out on firing at any given temperature. This is most likely a viscosity effect, an increase in alkali causing a decrease in viscosity and hence easier transformation of anatase to rutile. If the higher alkali frit were fired at a lower temperature, the viscosity, and hence the anatase/rutile ratio, would be the same as that of the frit having lower alkali content, but fired at higher temperatures. On the other hand, the higher the firing temperature, the more direct conversion of anatase to rutile will occur.

From these investigations it is evident that to obtain cold neutral whites with TiO_2-opacified enamels, the TiO_2 which crystallises on firing must be in the anatase crystalline form, and conditions favourable to the formation of rutile, namely, incomplete smelting, reducing conditions, and high firing temperatures, must be avoided.

In conclusion, the Author wishes to express his thanks to the directors of British Titan Products Company, Limited, for permission to publish this Paper. Thanks are especially due to Dr. W. Hughes for the X-ray examinations, and to Mr. S. G. Tinsley and Mr. R. W. Ancrum for their sustained interest and encouragement.

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Metal-cased Brick

Chemically-bonded (unfired) basic bricks are being used in basic open-hearth furnaces in increasing quantities and their application has become standard practice in many firms. During the past few years, numerous trials have established beyond doubt that chemically-bonded bricks give longer life if jointed with metal plates. The fusion of the metal plate binds the brickwork together to prevent spalling and joint erosion. General Refractories, Limited, have recently commenced the manufacture of metal-cased bricks, under British Patent No. 546220. These bricks are cased on four sides and are made in three qualities:—"Ferroclad 10"—a chemically-bonded chrome brick; "Ferroclad 30"—a chemically-bonded chrome magnesite brick, and "Ferroclad 70"—a chemically-bonded magnesite chrome brick.

These "Ferroclad" bricks are made in normal standard sizes and are recommended for use in front walls, back walls and ends of basic open-hearth furnaces; walls and ends of copper reverberatory furnaces; in certain cases for the side walls of electric furnaces, and for certain positions in soaking pits. The chief advantages claimed are as follow:—The metal case, being bonded to the brick during manufacture, adheres rigidly to the brick and avoids all looseness between brick and plate; the necessity of stocking or handling loose plates and the risk of accidents due to handling loose plates is avoided; there is no damage to bricks in transit; no jointing material is required; easier and quicker installation is followed by considerable saving of labour; spalling is eliminated; air infiltration is reduced or eliminated; the bricks are suitable for hot repair work and they have regularity of size and shape and longer life. Full technical information is available from General Refractories, Limited, Genefax House, Sheffield, 10.

Your Eyes. This publication, issued by Safety Products, Limited, St. George's House, 44, Hatton Garden, London, E.C.1, takes the form of a 14-page mimeographed pamphlet and covers all forms of eye protection. Especially interesting are the sections dealing with fettlers', welders' and furnacemen's goggles. The developments in these fields have been truly remarkable and to-day practically all the earlier inconveniences have been removed. The pamphlet is available on writing to Department D.W., at the Hatton Garden address.

Furnace Safeguard. Elcontrol, Limited, of 28a, Tilehouse Street, Hitchin, Herts, have issued a six-page leaflet which illustrates and describes a device for cutting-off fuel feed should a burner flame fail to function. This eliminates a potential cause of explosions.

THE NORTHERN SECTION of the Institute of Vitreous Enamellers proposes to hold a social evening on January 18. Further information may be obtained from the honorary secretary, Mr. T. J. McArthur, The Rustless Iron Company, Limited, Keighley.

Company News

The paragraphs below have been extracted from statements circulated to shareholders, speeches made at annual meetings, and other announcements.

Dorman, Long & Company, Limited:—The first stage of the company's major development plan was the installation of central ore-unloading equipment and ore-preparation plant at the Cleveland works, together with a private railway line across the Lackenby site linking the Cleveland and Redcar works. These two projects came into operation during the year. The second stage which involves capital expenditure of over £8,000,000 has been put in hand. This includes the building of the projected open-hearth steel plant at Lackenby with a capacity of 10,000 tons of ingots per week, the extension of the new ore-preparation plant and the installation of new blast-furnace ancillary equipment at the Cleveland works.

Kayser, Ellison & Company, Limited, steelmakers, of Sheffield (MR. L. A. K. HALCOMB):—Output shows an increase over the previous year, due, in some measure, to the introduction of new plant. While export markets are difficult, our export turnover has increased very satisfactorily, including increased sales to dollar countries. The order-book is not so heavy in general as at this time last year, but we have a satisfactory amount of work before us in all departments for some time ahead. The labour position is still very unsatisfactory, as we are always short of experienced men.

Duffield Iron Corporation, Limited, London Wall, London, E.C.2:—The directors are approaching the Board of Trade to obtain instructions for the closing down of the company. They state they have considered the position of the company following the death of the chairman and managing director in Australia on July 22, and have come to the conclusion that it would not be in the interests of the members for them to endeavour to raise further finance to carry on Mr. Duffield's research.

Personal

MR. GUY NICHOLSON has resigned from the boards of the Sheepbridge Company, Limited, and Sheepbridge Engineering, Limited.

SIR CHARLES BRUCE-GARDNER has been elected vice-chairman of Crompton Parkinson, Limited, manufacturing electrical engineers, of Chelmsford.

DR. J. W. MCDAVID, of Imperial Chemical Industries, Limited, has been appointed chairman of the Federation of British Industries' Scottish Regional Council.

MR. GEORGE WEST BYNG, a director of Dorman, Long & Company, Limited, has been re-elected chairman of the Tees Conservancy Commission for the fifth successive year.

MR. SOMERS BROWN has resigned from the board of the Parsons Marine Steam Turbine Company, Limited. Wallsend, owing to ill-health. He has been with the company for 46 years.

MR. J. WOODESON has succeeded his father, the late Mr. W. A. Woodeson, as chairman of Clarke, Chapman & Company, Limited, manufacturing marine engineers, etc., of Gateshead. MR. W. O. HENRIQUES has been appointed vice-chairman and MR. J. E. ELLIS a director of the company.

MR. C. H. BRADBURY, M.I.C.E., M.I.Mech.E., has been appointed chief engineer of Petters, Limited, small engine division, at Staines. He will be in charge of all technical matters relating to the range of engines produced at the Staines factory. Mr. Bradbury served his apprenticeship with Ruston & Hornsby, Limited, and was their chief research engineer from 1938 to 1948. This year he was appointed chief research engineer of Ruston & Hornsby, Limited, and Davey, Paxman & Company, Limited (Colchester).

Foreign Iron and Steel Prices

Prices shown in the appended table give an indication of the prices being paid for raw materials in certain countries following devaluation compared with our own. All the prices are expressed in our own currency and are domestic net quotations per ton of 2,240 lb. delivered to a typical consuming point, including, where necessary, an appropriate rail carriage. As, however, the foreign prices are shown delivered to points not too far from producing works, there will be some prices in large countries which are considerably higher. The prices are basis prices and have been calculated at current official rates of exchange. We are indebted to Darby & Company, Birmingham, for this information.

	Durham foundry coke.	High-phosphorus foundry pig-iron.	Re-rolling mild-steel u.t. billets.	Mild-steel merchant bars, basis.	Mild-steel plates, basis.
	£ s. d.	£. s. d.	£ s. d.	£ s. d.	£ s. d.
Great Britain	5 8 10*	9 18 0*	16 16 6*	22 6 0*	20 17 0†
France	—	—	19 8 6	26 4 3	31 9 0
Belgium‡	8 12 9	14 17 3	—	22 2 9	24 13 0
U.S.A.§: May, 1949 ..	9 3 6	20 5 0	22 4 6	30 7 3	30 14 3
,, When £1 = $4·02..	6 4 0	13 2 0	16 4 7	20 8 2	20 16 0

* Delivered Black Country station.
† Delivered Midland area.
‡ Prices are moving and may continue to do so.
§ Prices are delivered to Eastern consuming point with a corresponding rail haul. There may be a number of higher prices and some lower.

Beginning of the Scottish Iron Age

An illustrated lecture entitled "Notes on the Early History of the Carron Company" was given on November 10 in Falkirk, by Mr. M. H. Metcalfe, deputy general manager of the Carron Company. The lecture was held under the auspices of Falkirk Archæological and Natural History Society.

Mr. Metcalfe said that to Dr. John Roebuck, of Sheffield, an eminent scientist and mineralogist, was due more than any other man the honour of being named as the founder of the iron industry in Scotland, which had its genesis at the works at Carron. Operations in connection with the erection of Carron Works were started during the autumn of 1759. At the end of that year an air furnace, erected on the ancient bloomery principle and operated by natural draught, was ready for operation. This was followed some months later by the construction of a larger form of blast furnace driven by bellows. The first day of January was a memorable one. On that day was begun the work of iron-making at Carron. The fuel principally in use at the time for the manufacture of iron was charcoal, but from the commencement at Carron, efforts were concentrated upon getting good results from the use of coal and in these success was achieved due greatly to the scientific knowledge of Dr. Roebuck, who, in 1762, patented a process for the refining of iron by means of coke as a fuel. Carron works were the first to use ironstone from the carboniferous formations of Scotland.

The Carron Company's first working collieries were at Quarole and Kinnaird. Trials and vexations in various ways—difficulties with workmen, shortage of water, and other hindrances—came upon the partners in plenty, but these were overcome with courage and competence. The foundations of the business were laid upon a solid basis. The creation of Carron Works might be said to have started the industrial revolution in Scotland; it was certainly the beginning of the iron age in Scotland.

The only source of power available was water and large reservoirs were constructed near the works, which were connected with the River Carron at Larbert Viaduct by means of a waterway called the Furnace Lade. In 1773, the Carron Company was granted a Royal Charter from King George III creating it into a body politic with power to sue and be sued as a legally established corporation.

Mr. Metcalfe continued by dealing with the works discipline and conditions of employment in early days. He gave a history of the company as ordnance manufacturers, making special reference to Carronade guns which were invented in 1778, and said this was a great step forward in the provision of efficient ships' artillery. It was a happy thought that the renowned commanders of Trafalgar and Waterloo placed complete confidence in guns and shot made at Carron Works. Mr. Metcalfe then referred to the development of the light-castings industry, and said the pioneers of Carron were men of vision, who made it their duty to invent new uses for cast iron. He mentioned that in these far-off days Carronshore was an important shipping port, having both a dry-dock and a repairing yard. Use of the company's private canal between Carronshore and the works was discontinued when the Forth & Clyde Canal was opened, which enabled larger vessels to be employed.

He concluded by referring to the company's activities as pioneers in railway construction, and said that in 1766 the company laid a stretch of rails from Kinnaird Colliery to the interior of the works at Carron, a distance of about two miles. Rails were made of wood covered with a sort of hoop iron.

British Steel and Oil Projects

E.C.A. Authorisations

The spending of $47 million (about £16,785,000) Marshall aid money in Britain for modernising and expanding steelworks and petrol refineries has been authorised by the Economic Co-operation Administration. In a report covering the projects approved during the first 18 months of the Marshall plan, the Administration said the $47 million represented about 11 per cent. of the total cost of nearly $410 million (about £146,420,000) of the projects in Britain.

About three-quarters of the overall total would be used to modernise and expand steel-manufacturing facilities—the largest in Europe—and the rest would go into the expansion of petroleum refineries. This represented about $303,200,000 (about £108,282,000) for the steel and iron industry, and about $106,400,000 (about £38,000,000) for petroleum refining.

The Marshall plan financing was broken down into $29,700,000 (about £10,600,000) for iron and steel projects and $17,300,000 (about £6,178,000) for petroleum projects.

The report said the large steel enterprises approved for sheet, strip, and tinplate for the Steel Company of Wales, Limited, in South Wales and the tubemaking plants for Stewarts and Lloyds, Limited, at Corby should "make a substantial contribution to Britain's recovery." Britain had received approval, the report added, for two refinery expansion projects at Shell Haven and Llandarch to enable it to process additional crude oil (from the Middle East) and "thus decrease expenditure for imported refined products."

Obituary

MR. ROBERT FULTON PATERSON, late of David Rowan & Company, Limited, marine engineers, etc., of Glasgow, died recently.

MR. JOHN M. ANDERSON, who died suddenly on November 18, was chairman of Alexander Anderson & Sons, Limited, boilermakers, etc., of Motherwell.

MR. WILLIAM SWORD BACON, late of Smith & Wellstood, Limited, boiler and grate manufacturers, of Bonnybridge, Stirlingshire, died last week. He was 83.

Recent Wills

PRITCHARD, R. O., chief metallurgist of the Widnes Foundry & Engineering Company, Limited ... £2,527

CROSSLEY, MAJOR ERIC, a late director of Crossley Bros., Limited, oil-engine manufacturers, and Crossley Motors, Limited, Manchester £79,265

Correspondence

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

SURFACE ROUGHNESS OF CASTINGS

To the Editor of the FOUNDRY TRADE JOURNAL

SIR,—With reference to the article "Surface Roughness of Castings," published in the FOUNDRY TRADE JOURNAL dated November 10, 1949, I should like to point out that the article consists of an extract from a report presented at the Meehanite Research Institute Conference in Scotland in 1946. The surface meter illustrated was the original model developed in this country for the specific purpose of measuring casting surface roughness *in situ*—the meter can be taken to the casting when necessary. The basic principle of operation is maintained in the more recent models in use.

Regarding the comment in your editorial about classification by a simple number, the classification adopted is made with reference to actual measurement. The range within each class is based upon geometrical progression, not logarithmic as stated. For your information I enclose a diagrammatic comparison chart (Fig. 1) of the classes, with photographs (Fig. 2) representative of sample surfaces.

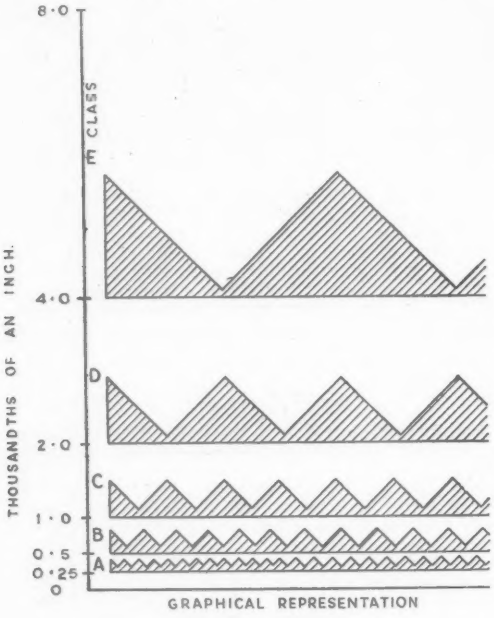

FIG. 1.—DIAGRAMMATIC COMPARISON CHART FOR SURFACE ROUGHNESS.

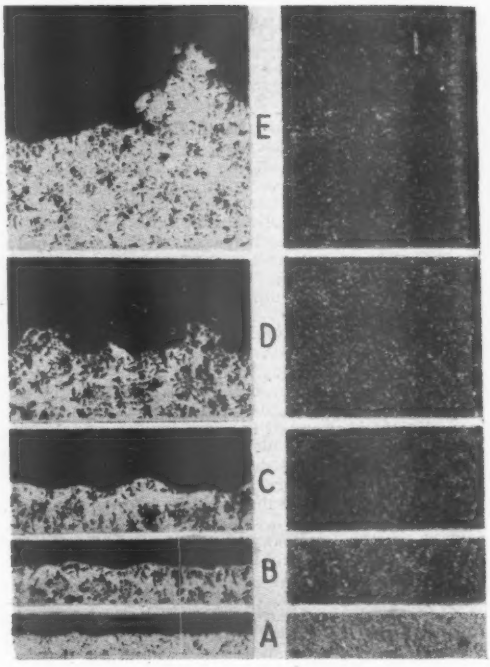

FIG. 2.—PHOTOGRAPHS SHOWING SURFACES OF CASTINGS (LEFT, PROFILE × 25; RIGHT, ACTUAL SURFACE).

In practice, the general range of castings falls within classes B, C, and D. The finest commercial finishes such as produced on cast-iron plaques and file-finish dies fall in class B; general automobile, refrigerator, *etc.*, castings, in class C. Few instances of class-A surface roughness are produced on general commercially-produced iron castings at the present time. Class-E surfaces are required for certain castings which must be tar dipped or similarly treated.—Yours, *etc.*,

G. HOBMAN,
Service Manager, Southern Europe.

The International Meehanite
Metal Company, Limited.

November 17, 1949.

STANTON-DALE

REFINED PIG IRON

Designed to meet the demands of high quality castings, which are, strength, machineability, and resistance to wear.

All these can be secured by using Stanton-Dale Refined Pig Iron in your cupolas.

The above illustration shows a group of castings made by Messrs. Goodbrand & Co. Ltd., Stalybridge, Cheshire.

PROMPT DELIVERY

THE STANTON IRONWORKS COMPANY LIMITED NEAR NOTTINGHAM

Imports and Exports of Iron and Steel

The following tables, based on Board of Trade returns, give figures of imports and exports of iron and steel in October. Comparative figures for the same month in 1947 and 1948 are given for purposes of comparison.

Total Exports of Iron and Steel

Destination.	Month ended October 31.		
	1947.	1948.	1949.
	Tons.	Tons.	Tons.
Channel Islands	653	1,385	1,467
Gibraltar	299	551	109
Malta and Gozo	215	493	326
Cyprus	333	294	187
British West Africa	5,606	6,025	11,643
Union of South Africa	14,174	15,482	8,971
Northern Rhodesia	721	2,399	1,693
Southern Rhodesia	4,525	4,471	5,816
British East Africa	5,613	5,034	7,590
Mauritius	294	273	668
Bahrein, Koweit, Qatar, and Trucial Oman	2,897	1,691	798
India	11,044*	6,271	6,804
Pakistan		1,763	2,582
Malaya	3,028	4,567	5,480
Ceylon	1,617	1,748	3,328
North Borneo	648	129	309
Hongkong	1,415	4,432	2,818
Australia	4,067	8,306	25,479
New Zealand	3,150	6,218	13,627
Canada	2,415	1,762	4,985
Bermuda	6	68	101
British West Indies	1,840	6,424	7,147
British Guiana	210	525	679
Anglo-Egyptian Sudan	859	643	1,921
Other British countries	780	1,320	1,056
Irish Republic	5,327	4,808	5,722
Russia	2	—	111
Finland	7,893	6,025	8,681
Sweden	8,158	5,232	4,246
Norway	4,365	8,214	6,772
Iceland	287	192	510
Denmark	11,449	11,376	8,422
Poland	239	501	93
Germany	33	24	20
Netherlands	9,193	10,498	8,280
Belgium	1,790	682	772
France	1,848	1,008	3,736
Switzerland	1,518	969	2,145
Portugal	608	2,257	1,146
Spain	315	456	700
Italy	148	240	160
Hungary	48	24	76
Czechoslovakia	392	2	26
Greece	873	286	228
Turkey	953	1,073	2,024
Dutch East Indies	918	3,161	2,162
Dutch W. India Islands	1,038	648	780
Belgian Congo	7	82	225
French W. and Eq. Africa	16	16	28
Portuguese East Africa	807	234	349
Canary Islands	326	722	111
Syria	13	80	510
Lebanon	1,365	3,620	1,681
Palestine (Israel)	2,596	778	1,499
Egypt	2,156	4,695	5,470
Morocco	210	36	34
Iraq	6,251	3,188	1,834
Iran	7,788	7,787	19,291
Burma	4,975	1,689	856
Siam (Thailand)	118	221	578
China	3,926	1,184	40
U.S.A.	184	3,500	229
Cuba	85	61	27
Colombia	295	889	840
Venezuela	4,154	7,402	3,068
Ecuador	256	231	85
Peru	840	144	1,686
Chile	359	1,029	699
Brazil	746	1,269	1,486
Uruguay	1,002	391	652
Argentine	5,788	15,617	16,566
Other foreign countries	1,752	2,228	3,794
TOTAL	169,819	197,043	234,034

* Figures for 1947 relate to British India.

Total Imports of Iron and Steel

From	Month ended October 31.		
	1947.	1948.	1949.
	Tons.	Tons.	Tons.
Australia	—	3,025	562
Canada	6,282	8,097	7,418
Other British countries and Irish Republic	3,134	278	1,572
Sweden	1,260	1,473	1,176
Norway	2,257	1,809	1,904
Germany	522	553	873
Netherlands	1,065	4,254	4,558
Belgium	11,877	34,925	19,769
Luxemburg	1,615	6,312	8,980
France	130	3,287	11,289
U.S.A.	6,255	5,652	15,590
Other foreign countries	22	323	570
TOTAL	34,419	69,988	74,261
Iron ore and concentrates—			
Manganiferous	7,520	18,700	—
Other sorts	690,424	734,698	750,409
Iron and steel scrap and waste, fit only for the recovery of metal	24,557	98,674	152,809

Exports of Iron and Steel by Product

Product.	Month ended October 31.		
	1947.	1948.	1949.
	Tons.	Tons.	Tons.
Pig-iron	861	120	1,130
Ferro-alloys, etc.—			
Ferro-tungsten	74	69	92
Spiegeleisen, ferro-manganese	311	233	569
All other descriptions	91	85	82
Ingots, blooms, billets, and slabs	128	148	174
Iron bars and rods	286	770	936
Sheet and tinplate bars, wire rods	110	292	187
Bright steel bars	2,211	2,177	1,733
Other steel bars and rods	14,242	12,474	15,758
Special steel	1,629	1,525	1,426
Angles, shapes, and sections	6,936	10,878	10,910
Castings and forgings	332	489	792
Girders, beams, joists, and pillars	948	1,272	3,548
Hoop and strip	4,372	3,851	4,948
Iron plate	99	633	1,155
Steel plate, ⅜ in. thick and over	9,893	12,231	20,146
Do., under ⅜ in. thick	9,098	14,878	15,035
Galvanised sheets	5,908	11,681	10,628
Tinplates	11,653	17,310	22,016
Tinned sheets	207	400	135
Terneplates	30	31	43
Decorated tinplates	437	503	4
Other coated plates	266	350	646
Cast-iron pipes, up to 6-in. dia.	5,506	5,854	8,334
Do., over 6-in. dia.	3,203	6,625	10,181
Wrought-iron tubes	22,838	25,945	32,442
Radiators, central-heating boilers	338	220	314
Railway material	18,051	21,740	20,945
Wire	3,886	3,811	5,521
Cable and rope	2,345	2,048	2,764
Netting, fencing, and mesh	1,487	1,444	1,832
Other wire manufactures	513	1,417	1,285
Nails, tacks, studs, etc.	690	654	584
Rivets and washers	1,109	960	616
Wood screws	249	222	299
Bolts, nuts, and metal screws	1,820	2,083	2,501
Stoves, grates, etc. (excl. gas)	726	753	709
Do., gas	196	280	232
Sanitary cisterns	73	122	197
Baths, sinks, etc.	295	856	1,051
Fencing material	528	198	816
Anchors, etc.	710	1,018	1,232
Chains, etc.	812	907	993
Springs	372	629	685
Hollow-ware	8,335	4,430	7,052
All other manufactures*	25,615	22,427	21,355
TOTAL	169,819	197,043	234,034

* Figures for 1949 are not completely comparable with those for previous years.

WORKINGTON FOUNDRY IRONS

THE UNITED STEEL COMPANIES LTD

Workington Irons, made from particularly pure hematite ores, are esteemed by foundrymen for admixture with other irons to improve the quality and physical properties, especially for ingot mould castings, machine castings, chemical plant, etc. All Workington irons are supplied in machine-cast form, free from sand, saving coke in the cupola, and being most convenient for handling and mixing.

WORKINGTON IRON & STEEL COMPANY

WORKINGTON Telephone: Workington 206 Telegrams: "Mosbay," Workington CUMBERLAND

Branch of The United Steel Companies Limited.

W. 78.

Raw Material Markets

Iron and Steel

The pig-iron position is easier, mainly because of a slight, but unmistakeable, shrinkage of activity in the foundry trades. Pressure for light castings has undergone some relaxation, and although conditions in the heavy engineering and jobbing foundries are variable, it is clear that some concerns are working below capacity levels. Hence, it appears that although blast-furnace outputs have not increased, the call for most descriptions of pig-iron can be more readily satisfied. There are still no substantial reserves of high-phosphorus iron, and the output of hematite is passing promptly into consumption. Refined-iron requirements, however, are a little less urgent and small consignments are being shipped under licence.

Heavy imports of Continental semis have not yet been fully digested and as re-rollers have to encounter keener foreign competition in marketing their products, fresh business in heavy billets is not very brisk. Good supplies of blooms and slabs are also available, but smaller-sized billets are still wanted and there is a well-sustained demand for sheet bars which seems likely to continue for some time.

Heavy backlogs of orders for plates and sheets promise full-scale activity at the mills throughout the first quarter of the coming year. Nor is there any perceptible slackening in the current demand for steel sections and joists. Reports from the shipyards, however, indicate that some increase in the quotas have been sanctioned and more steel has, in turn, helped to accelerate the rate of operations in the yards. Home demand for small bars and light sections, probably affected by keen Belgian competition, is disappointing, but sheetmakers have such a heavy volume of orders in hand that new bookings are on a limited scale.

Non-ferrous Metals

As might be expected, the rate of decline in the price of tin has slackened, with a consequent narrowing of the backwardation. The turnover has been modest, but there is no reason for despondency, since it was expected that after being closed down for many years the newly-opened market would take time to settle down. Many traders are of the opinion that the abandonment of control should have been decided upon earlier, say 12 months ago, before the position became top-heavy. Moreover, it is suggested that, so far as tin is concerned, revaluation of the £ would have been more easily dealt with had a free market been in operation when the change was announced. The moral to be drawn from this would appear to be that the Government would be well advised to give consideration to the early decontrol of copper stocks, which in the United Kingdom have reached a very high level.

Metal Exchange tin quotations were as follow:—

Cash—Thursday, £640 to £645; Friday, £637 10s. to £640; Monday, £635 to £636; Tuesday, £624 to £625; Wednesday, £617 10s. to £620.

Three Months—Thursday, £595 to £600; Friday, £599 to £600; Monday, £585 to £587 10s.; Tuesday, £580 to £581; Wednesday, £578 10s. to £580.

Relative to current consumption, the copper tonnage is not so high as tin, but it is by no means inconsiderable. Some action is certainly required, for it is hard to believe that a free market in London would register, for long at any rate, a value of £153 per ton for electrolytic copper. Nor, for that matter, a price of £148 12s. 6d. for Bessemer grades. In some quarters it is felt that matters will reach a stage in copper where the authorities will have no way out of their difficulties, but to restore the facilities afforded by a free market.

The weakness in lead has continued and the quotation was reduced twice last week, on Monday by £2 to £101, and again on Wednesday by a further £4 to £97 per ton. For this the downward trend in the metal's price in the United States must be blamed; the quotation fell to 12 cents, and even at that level does not look any too strong. Zinc, too, has been showing an easier tendency and has reacted to 9¼ cents per lb. This compelled an adjustment of the U.K. price to £85 10s. per ton, a somewhat disappointing development in view of the manner in which this market has moved up recently. Scrap prices are steady.

Increases of Capital

Details of increased capital have been announced by the following companies:—

PATENT DIE-CASTINGS COMPANY, LIMITED, London, S.W.1, increased by £50,000, in 5s. ordinary shares, beyond the registered capital of £100,000.

W. G. BAGNALL, LIMITED, engineers, boilermakers, etc., of Worcester, increased by £40,000, in £1 ordinary shares, beyond the registered capital of £60,000.

HATTERSLEY (ORMSKIRK), LIMITED, engineers, etc., of Ormskirk, Lancs, increased by £250,000, in £1 5 per cent. cumulative preference shares, beyond the registered capital of £250,000.

JAMES AUSTIN & SON (DEWSBURY), LIMITED, iron and steel merchants, etc., of Thornhill, Dewsbury, increased by £50,000, in £1 ordinary shares, beyond the registered capital of £70,000.

W. A. BAKER & COMPANY, LIMITED, founders, engineers, etc., of Courtybella, Newport, Mon, increased by £300,000, in £1 ordinary shares, beyond the registered capital of £500,000.

JOB WHEWAY & SON, LIMITED, ironfounders, etc., of Walsall, increased by £45,000, in 30,000 preference shares of £1 and 300,000 ordinary shares of 1s. each, beyond the registered capital of £75,000. Each of the 55,000 ordinary shares of £1 each has been sub-divided into 20 ordinary shares of 1s.

Ground Sulphur Price Increases

The Board of Trade has made an Order, effective today (Thursday) increasing the maximum prices of ground sulphur by 33s. per ton. This is due to the change in the sterling-dollar exchange rate. Copies of the Order, the Ground Sulphur (Prices) (Amendment No. 3) Order, 1949 (S.I. 1949, No. 2195), can be obtained, price 1d., from H.M. Stationery Office.